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VOL. 14, NO. 10, OCTOBER 1958

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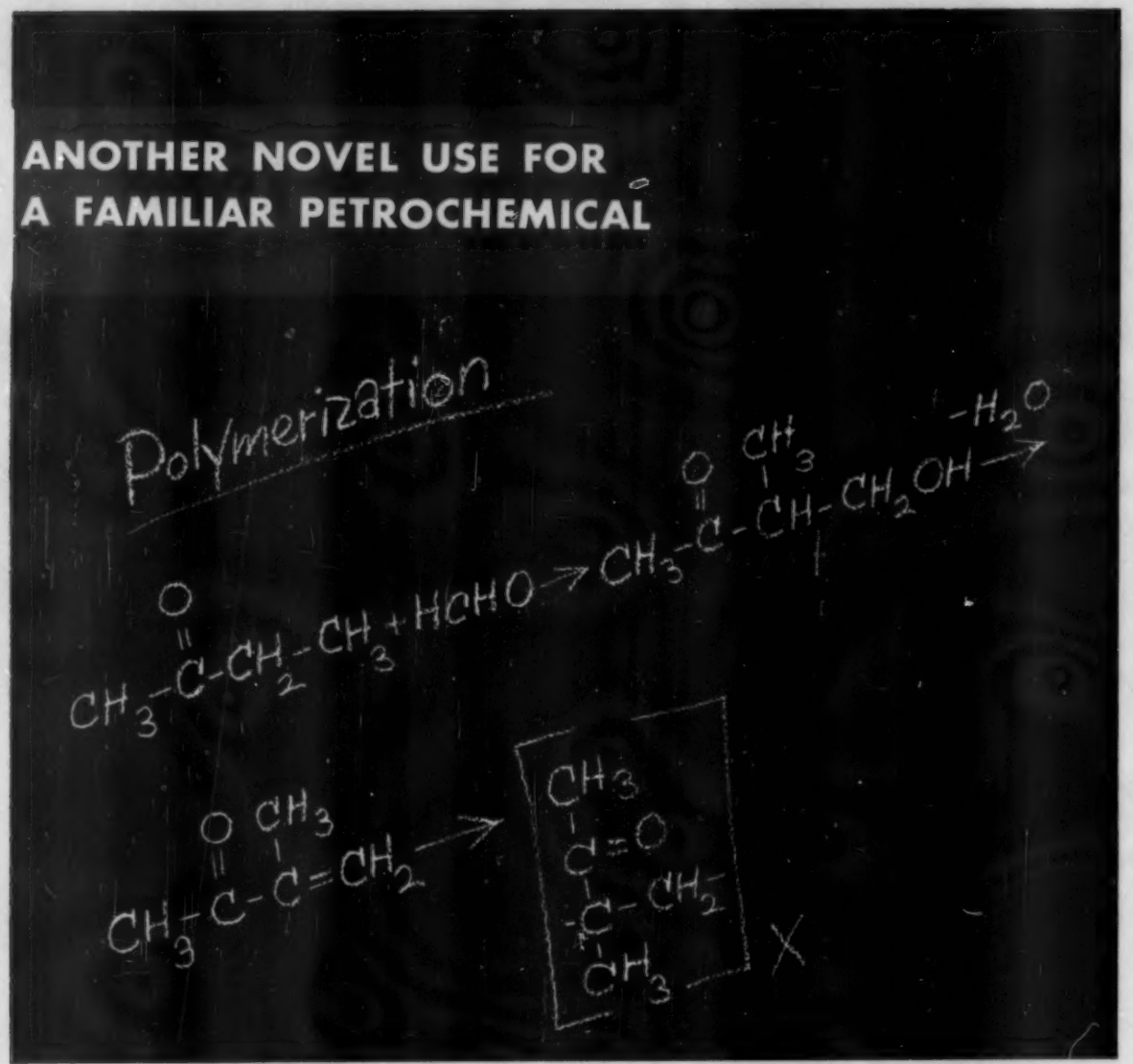

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Charles E. Rhine
Editor

EDITOR'S NOTEBOOK

POLYMER SCIENCE

—a new Journal feature

The *SPE Journal* will initiate its newest feature "Polymer Science" in the November issue. It is hoped that this feature will provide information of interest to the growing number of our members engaged in or interested in basic studies of polymer behavior. For the present, we envision this feature as consisting largely, but not solely, of review articles on the status of research in various fields of polymer science or reviews discussing basic polymer behavior written by an expert in each field. Any comments on this definition or suggestions for articles will be most welcome.

The feature will be edited by Dr. Irvin Wolock who has been active for many years in our Baltimore-Washington Section serving as its president in 1956. He obtained a bachelor's degree in chemical engineering from The Johns Hopkins University in 1943. He then worked on the Manhattan Project at the S.A.M. Laboratories at Columbia University, both as a civilian and while in the Army. In 1946, he returned to The Johns Hopkins University where he was awarded his doctorate in chemical engineering in 1950. From November 1950 to December 1957, he was a member of the Plastics Section at the National Bureau of Standards. He is presently employed in the Ballistics Branch, Mechanics Division at the U. S. Naval Research Laboratory in Washington, D. C.

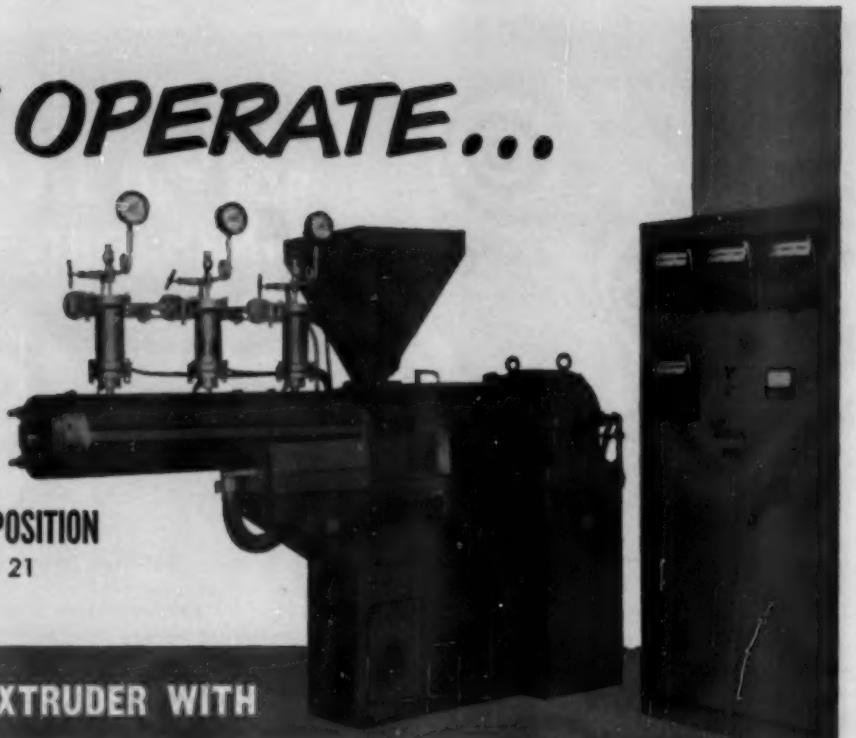
It is quite appropriate that the initial article of this feature will be one written by Professor Herman Mark, Director of the Polymer Research Institute of the Polytechnic Institute of Brooklyn. Professor Mark is one of the world's pioneers and leading authorities in the field of polymer science. The subject of his paper will be "Recent Progress in Polymer Science." We are quite pleased that Professor Mark has agreed to initiate this feature. We are confident that it will set a high standard for future articles to meet.

TWORZYWA

—can you read it?

The above is the title of the Bulletin of the Institute of Plastics Research of Poland. We are now receiving copies of *Tworzywa* at our office in exchange for copies of the *SPE Journal*. It is very likely that this magazine will contain items of interest to SPE members. We are therefore looking for a plastics engineer who will read this bulletin each month and write abstracts of important items for publication in our Plastics Around the World feature. We will supply a free copy of *Tworzywa* each month to a member who will abstract the articles for publication under a by-line. If you are interested in this rewarding job, please write the Editor stating your qualifications.

SEE IT OPERATE...



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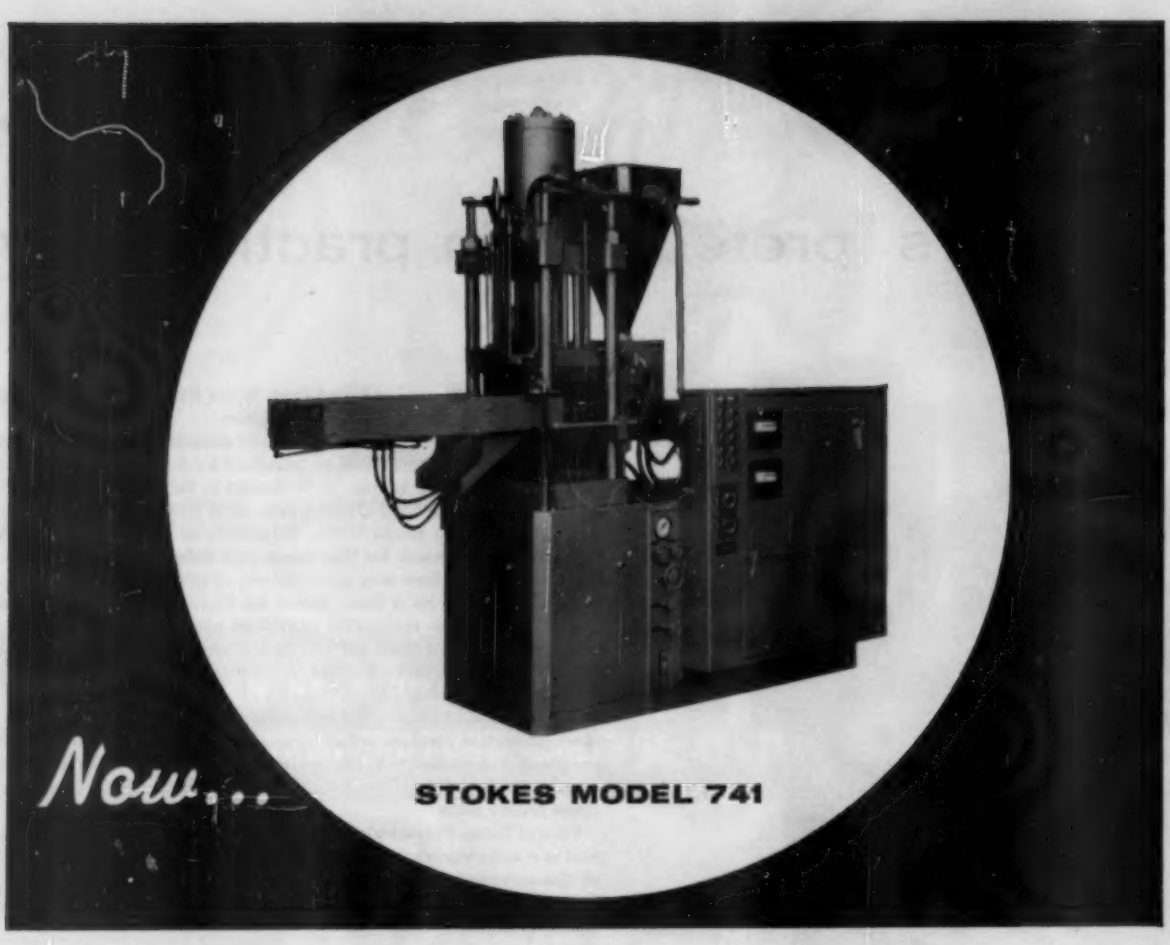

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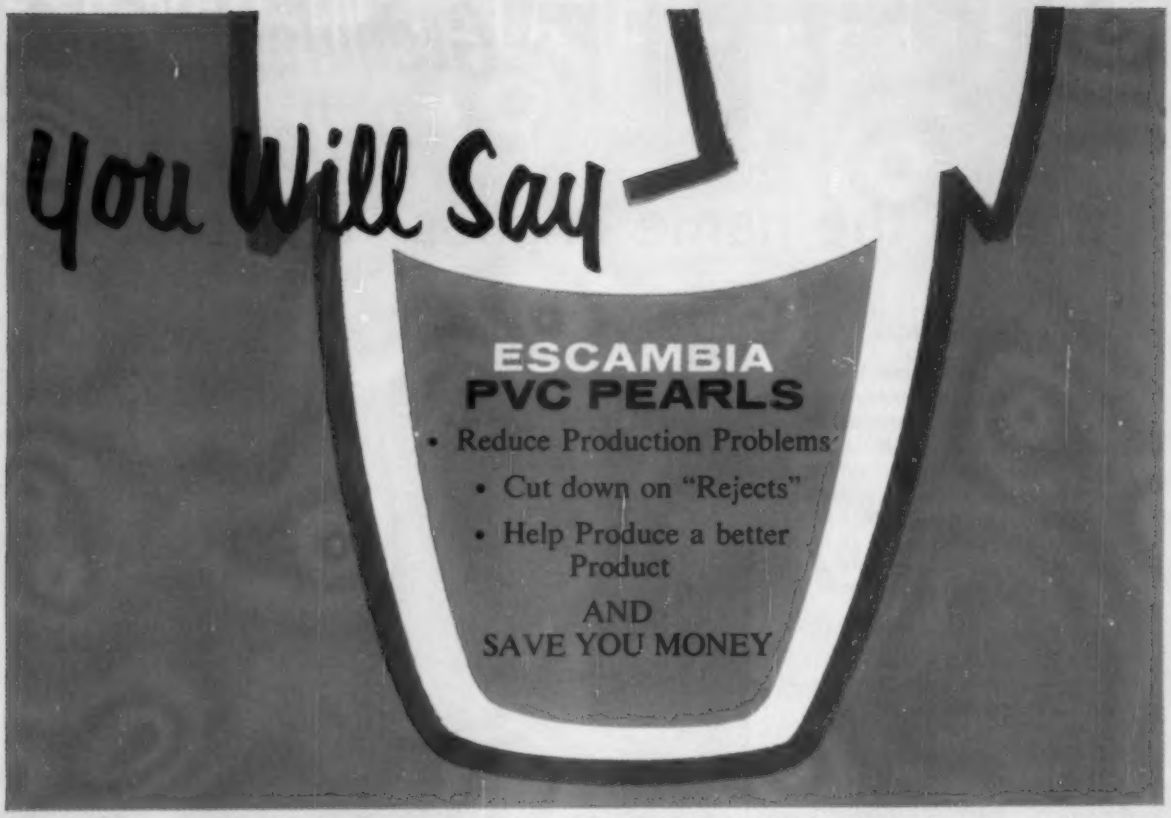

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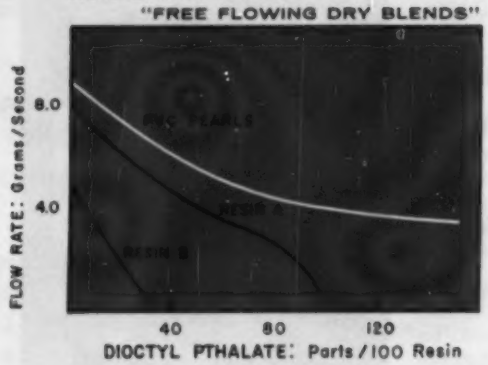

Compare the flow rate of Escambia PVC Pearls at various plasticizer levels with conventional resins ("Resin A" and "Resin B") in the chart above. (Tests made through 60° stainless steel funnel having a ½-inch opening.)

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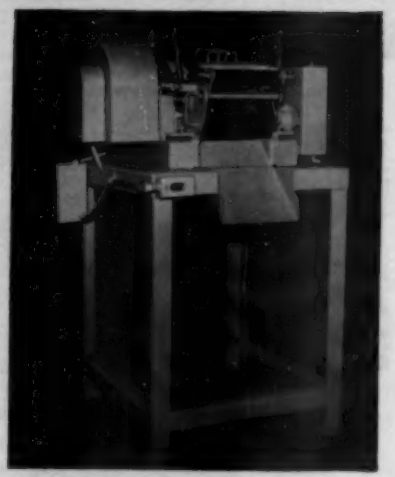

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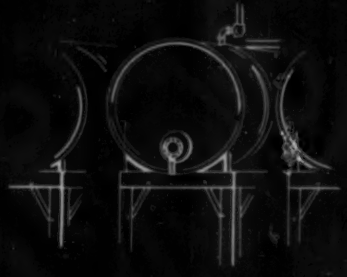

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TYPICAL PHYSICAL AND CHEMICAL PROPERTIES OF FORTIFLEX

Properties of Fortiflex "A" Related to Melt Index

PHYSICAL PROPERTIES	ASTM METHOD	UNITS	FORTIFLEX RESINS A-20	A-70	A-250	A-500
Melt Index	D-1238-52T	—	0.2	0.7	2.5	5.0
Heat Distortion Temp. (66 psi)	D-648-45T	°F.	185	185	180	180
Brittleness Temp.	D-764-52T	°F.	—200	—180	—160	—100
Impact Strength, Izod (¼" x ½" injection-molded bars)	D-256-54T	ft. lb./in. notch	23	18	13	3
Tensile Strength, Max., 0.2 in./min.	D-638-52T	psi.	3700	3600	3500	3300
Elongation, First Tensile Yield Point	D-638-52T	%	25	25	25	25

Properties of Fortiflex "A" Not Affected by Melt Index

PHYSICAL PROPERTIES	ASTM METHOD	UNITS	VALUE
Density		g/cc.	0.96
Refractive Index	D-542-50	$N^{25}D$	1.54
Hardness, Shore D	D-676-49T		65
Stiffness	D-747-50	psi.	150,000
Water Absorption (⅛" specimen, 24 hrs. immersion @ room temp.)	D-570-54T	%, wgt. gain	<0.01
Flammability	D-635-44	in./min.	1.0

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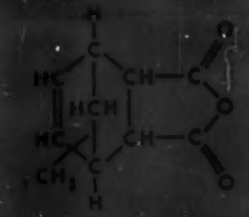
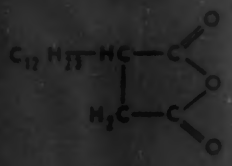


the methyl group replaces one of the hydrogens

DODECENYL SUCCINIC ANHYDRIDE



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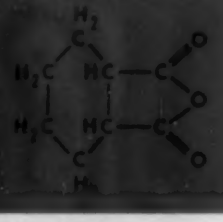


* as described in U.S. Patent #2,324,483

Allied Chemical

NATIONAL ANILINE DIVISION
40 RECTOR STREET, NEW YORK 6, N. Y.

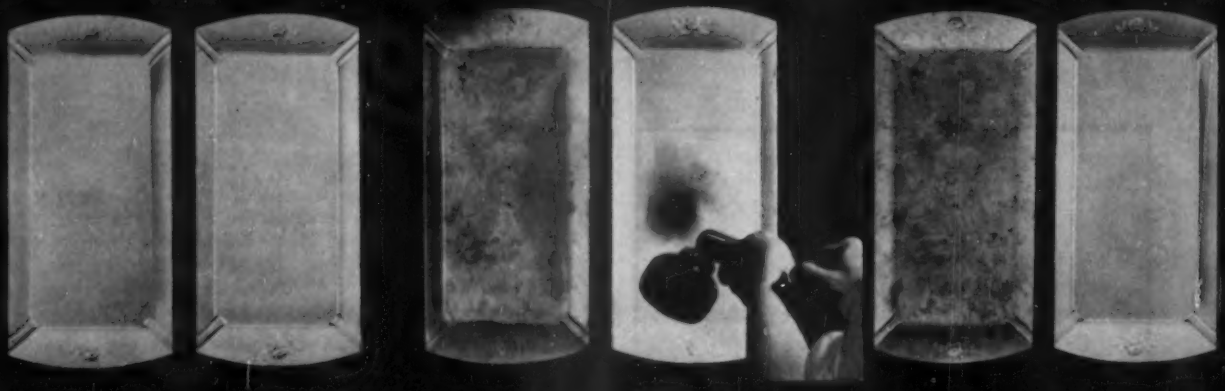
Akron Atlanta Boston Charlotte Chattanooga Chicago Greensboro Los Angeles New Orleans Philadelphia Portland, Ore. Providence San Francisco Toronto

NOW NEW FIRST and ONLY

static dissipating styrene molding powder

LUSTREX LO-STAT

Translate this test into new production economies and sales advantages:



1. Two trays from same mold. Left: molded of standard material. Right: molded of Lustrex Lo-Stat.

2. Charcoal dust is sprayed on both trays.

3. Result! Dust pattern on standard tray corresponds to static electric charge. Tray of Lustrex Lo-Stat is practically clean. The little charcoal remaining is easily tapped off.

Think what Lustrex Lo-Stat can mean in keeping housewares clean and appealing, how much longer signs, displays and packages will stay attractive. Air conditioner and fan grills are other moldings that will be improved. There are dozens of jobs that Lustrex Lo-Stat dust-resistant styrene can do better. And production economies include the elimination of spraying and bathing; open storage and simplified handling. Lustrex Lo-Stat is in full production. Send for a trial quantity now along with complete technical data. Monsanto Chemical Company, Plastics Division, Room 407, Springfield 2, Mass.

Monsanto

LUSTREX: REG. U. S. PAT. OFF.

HERE ARE FACTS ON HOW

WITH TODAY'S

TYPICAL PROPERTIES

High-Density Polyethylene

Melt Index, dgm/min	0.3–8.5*
Secant Modulus, at 1% elongation, psi	90,000–150,000*
Yield Strength, psi	3,100
Tensile Strength, psi	3,300
Tensile Impact, ft. lbs/in^3	70
Elongation, per cent	50
Hardness, Durometer "D"	56
Dielectric Constant, 50MC	2.34
Dissipation Factor, 50MC	0.0002
Melting Temperature Range, deg. C	120–130

**Depending on specific product*

Q. Is high-density just "another" polyethylene?

A. With a density range from .942 to .965, BAKELITE Brand high-density polyethylenes are, in many respects, completely new materials. They offer improved rigidity and excellent dimensional stability at both high and low temperatures. Resistance to chemicals is greater and vapor and liquid permeability is reduced.

Q. Is it possible to obtain all densities from one polyethylene supplier?

A. Yes, with the addition of these high-density materials, the BAKELITE Brand polyethylene line now includes densities from .915 to .965.

Q. Can existing molding equipment be used?

A. Because BAKELITE high-density resins permit faster molding cycles, some modifications in runner, sprue and gating design may be required. Good principles of mold design should be followed. All other techniques need little or no change.

1035

KNOW-?

YOU CAN SAVE

NEW BAKELITE BRAND High-Density Polyethylene

Q. What are the advantages of BAKELITE Brand high-density polyethylene for injection molding?

A. BAKELITE Brand high-density polyethylene compounds permit thinner sections without loss of rigidity or load-bearing characteristics and offer easier flow with higher melt index for multiple-cavity molding.

Q. What are the advantages for blow molding?

A. BAKELITE Brand DMDA-4901 is capable of withstanding sterilization temperatures of 250°F. at 15 psi. steam pressure. It provides stiffness 4 to 5 times that of low-density resins, reduced permeability, excellent printability.

Q. Can Bakelite Company provide a compound for specific needs?

A. There are presently nine BAKELITE Brand high-density polyethylene compounds incorporating properties that meet the over-all requirements of customers for molding, extrusion coating, film extrusion, monofilaments, contour extrusion and sheet extrusion for vacuum forming.

Q. What factors assure uniformity?

A. In new Bakelite Company plants for production of high-density polyethylenes, processes are fully automated for quality control. Newly developed blending equipment produces blends with batch-to-batch uniformity in box-car quantities. Over all, there is the 40-year experience of Bakelite Company in producing quality plastics.

Q. Is additional technical data available?

A. Yes, in technical bulletins obtainable on request to your Bakelite Company Technical Representative, or by writing Dept. JS-33G.

Products of UNION CARBIDE *Corporation*

BAKELITE COMPANY, Division of UNION CARBIDE CORPORATION, 30 East 42nd Street, New York 17, N. Y.
In Canada: BAKELITE COMPANY, Division of Union Carbide Canada Limited, Toronto 7
The terms BAKELITE and UNION CARBIDE are registered trade-marks of UCC.

CYANAMID

PLASTICS NEWSFRONT

Midget Adding Machine New Step in Miniaturization

This telephone-size, 7½-pound adding machine, the *Add-Mate*, is Underwood Corporation's newest bid to reduce size and weight of business machines. Easily portable, it can be slipped into a desk drawer or under a counter when not needed. Contributing to its compactness and lightness is the attractive, two-toned housing of CYMAC SUPER* 201 methyl-styrene-acrylonitrile copolymer plastic.

THE COLORFUL TWO-PIECE HOUSING is molded of CYMAC SUPER. Shown above, respectively, are the complete unit, the unit minus the top section, and the inner sides of the top and bottom sections. CYMAC SUPER was selected because of its toughness, surface hardness, and resistance to heat, staining and denting. It is unaffected by the diester permanent lubricant applied to the mechanical assembly prior to encasement in the housing. The transparent, serrated tear-plate, also CYMAC SUPER, and the housing are injection-molded for Underwood by Nopco Plastics, Inc., Erie, Pa. *Trademark

AMERICAN CYANAMID COMPANY
PLASTICS AND RESINS DIVISION
32 D Rockefeller Plaza, New York 20, N. Y.

CYANAMID Plastics and Resins Division

In Canada: Cyanamid of Canada Limited, Montreal and Toronto
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these thermatic Series* extruder

features mean higher production on every job!

Simplified one piece cylinder with integrally cast-in Xalloy liner.

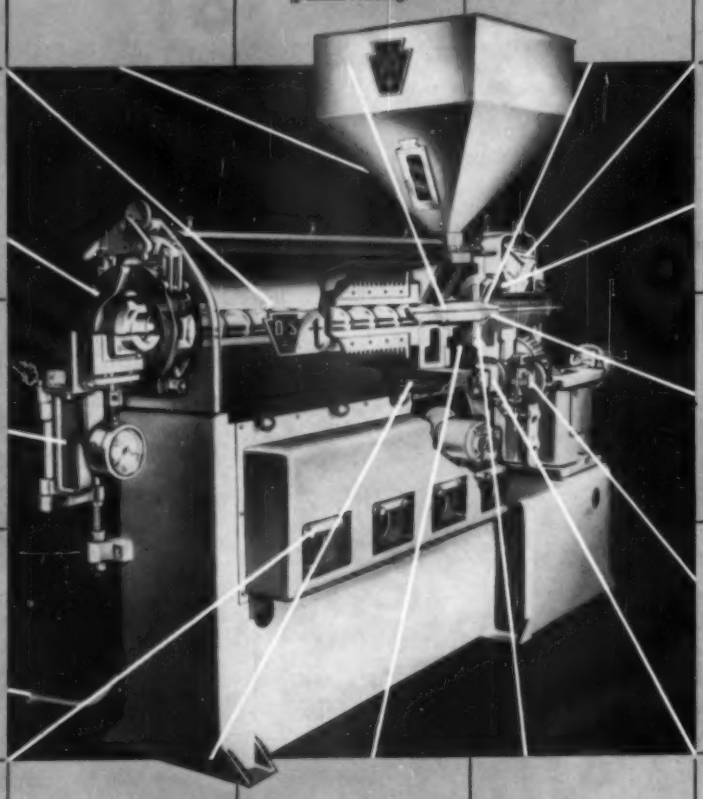
Extra large capacity stainless steel hoppers.

Screw flight extends back beyond the feed throat opening for improved powder and granule feeding.

Four-spline screw drive eliminates the eccentric screw rotation of a single key drive.

Helical gearing — smooth, efficient, free-running. Greatly increased horsepower capacity.

New stronger head clamp. Simplified opening and closing of head with positive safety shear pin arrangement.



Higher thrust bearing capacity. Extra-heavy separate thrust and radial bearings handle their respective loads individually to meet constantly increasing production requirements.

Improved hinged head support swings completely clear of the front of the extruder.

Tapered drive end of stock screw positively centers screw and simplifies removal.

Heaters and controllers completely wired for fast inexpensive installation.

Gear type oil pump, positively driven from input shaft, lubricates all bearings and gears regardless of speed.

Damper arrangement provides several gradients of natural draft cooling. Blowers provide high circulation for stubborn cooling jobs.

Air-tight oven effect adjustment by new second set of dampers for high temperature extrusion.

Access opening allows easy replacement of bronze feed throat bushing.

Labyrinth oil seals — simple non-wearing design. No oil seals or rings to replace.

Built-in direct drive stock screw electric tachometer.

Greater cylinder lengths standard on all extruder sizes with optional L/D ratios available. **2½", 3½", 4½", 6" and 8" models available.** The New D-S thermatic Series Extruders will outproduce — size for size — any other extruder on the market today. For complete specifications and details write to:

D-S **DAVIS - STANDARD**

Division of FRANKLIN RESEARCH CORPORATION

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*Patented

IN CANADA CONTACT E. V. LARSON CO. LTD., 572 QUEEN STREET EAST, TORONTO 2, ONTARIO
IN EUROPE AND THE STERLING AREA CONTACT FAWCETT, PRESTON & CO. LTD., BROMBOROUGH, ENGLAND

Plaskon Polyesters are

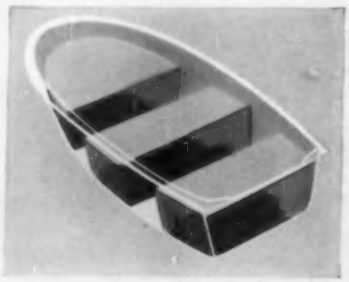
GOING

No doubt about it, polyesters are really going places—and fast! There are many good reasons for this . . . these versatile materials offer great freedom of design; unique color, translucency and surface effects; and dependable service, to mention only a few. As an example, note the great variety of products pictured here—including laminates, premix parts and polyurethane foams—all made with PLASKON Polyester Resins.

Wherever great strength combined with light weight are primary requirements, especially in relatively large units, PLASKON Polyesters—reinforced with glass fibers or other materials—are likely candidates. Other outstanding advantages: excellent electrical insulation, dimensional stability, a hard durable surface that resists weathering and chemical corrosion, good colorability—opaque or translucent.

PLASKON Polyesters play a leading role, too, in the booming market for polyurethane foams. Strong, *rigid* foams for thermal and acoustical insulation, flotation chambers, or protection against heat, cold, sound—flexible foams for vibration or impact absorption . . . whatever type of polyurethane you're looking for, we can supply the right PLASKON Polyester.

If you would like to know more about PLASKON Polyester Resins — and how they can serve you — **write to** Plastics and Coal Chemicals Division, 40 Rector Street, New York 6, New York. In Canada: Allied Chemical Canada, Ltd., 1450 City Councillors Street, Montreal, Canada.



POLYURETHANE FOAMS
PLASKON Polyesters for rigid foams can be foamed easily in place (as in this boat hull or in wall partitions) or in inexpensive molds on a batch or continuous basis.

PREMIX MOLDING
Cost-saving premix operation permits the rapid molding of reinforced parts with varying thicknesses, intricate contours or molded-in inserts. Used for automobile heater and radio speaker housings.

PLACES

MATCHED METAL MOLDING
For exact dimensional reproduction in every part. Molded under pressure and heat in metal molds to assure consistent mechanical performance, physical properties and rapid production. Examples: chairs, luggage, machine housings.

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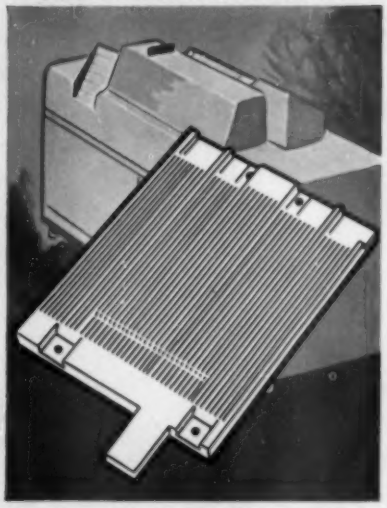
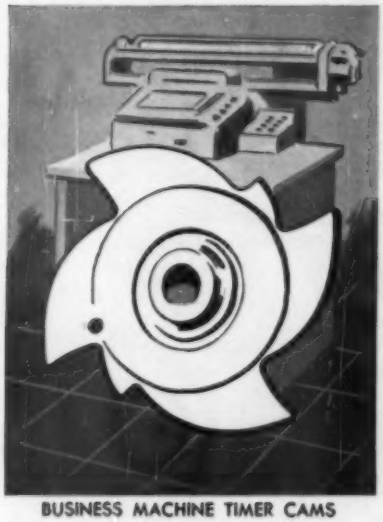
SPRINKLER KNOBS

TYPEWRITER BARS, KEYS, KNOBS

CARD TABULATOR BRUSH DIVIDERS

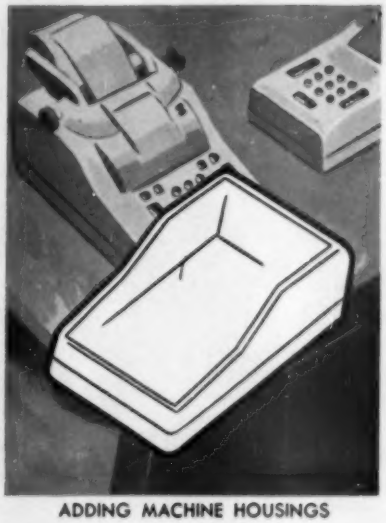


IMPLEX®



BUSINESS MACHINE TIMER CAMS

TEXTILE BOBBINS



ADDING MACHINE HOUSINGS

...the tough new plastic for equipment parts!

Write for IMPLEX *booklet, technical assistance on specific applications, and names of qualified* IMPLEX *molders.*

Tough IMPLEX, a modified acrylic for injection molding, offers cost reduction opportunities to manufacturers of many types of equipment and components. What's more, cost reduction may be accompanied by performance improvement, for IMPLEX has a remarkable combination of physical properties. It imparts toughness . . . stain resistance . . . stiffness . . . high surface gloss . . . corrosion resistance . . . dimensional stability . . . freedom from unpleasant odor . . . and ease of molding to complex shapes.

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PLASTICS ENGINEERS JOURNAL

Volume 14, Number 10, October, 1958

Plastics Take to the Road

Today's average automobile uses approximately eighteen pounds of plastics — a far cry from Vintage 1900 which saw the first side curtains made of cellulose nitrate.

Andrew W. Shearer
Market Research Editor
Automotive Industries

PLASTICS have come a long way in the automobile industry in the past few years. While some plastics materials have declined in usage, others have been developed to replace them, and, in many cases, surpass them in total poundage consumed. No longer looked upon as mere substitute materials, plastics are accepted on their own merits because they are doing a better job and are competitively priced.

There is a growing awareness among automotive engineers and stylists that the unique combination of properties offered by plastics permits designs which would not be possible with other materials. It is conservatively estimated that the 1958 composite car uses roughly 18 pounds of plastics materials, as compared to the 15¼ pounds which *Automotive Industries* estimated were used in the average 1956 automobile. This figure gains added force by contrast with the mere 11 pounds used in a typical 1954 car.

Even if the total passenger car output for 1958 reaches only 5.5 million units, the industry will still consume almost 100 million pounds of plastics. Although this total is impressive, it seems almost insignificant when compared with the potential for plastics applications during the next several years. By 1963 or sooner, the automobile industry can reasonably expect an annual sales volume of 7.5 to 8 million cars. During this same period, plastics applications may well grow rapidly to a per-car usage of 32 to 35 pounds. This would indicate a total annual consumption of over 200 million pounds—more than double the current rate.

It is the purpose of this article to review briefly each principal type of plastics from the viewpoint of its current and potential automotive applications. New applications in 1958 cars are pinpointed wherever possible.

THERMOSETTING PLASTICS

Alkyds

The alkyds provide adhesion, durability, color retention and flexibility to automotive and other fast-drying industrial lacquer finishes. They are also used extensively with urea and melamine resins in baking enamels. However, while butylated urea-formaldehyde resins combined with alkyds were formerly used extensively in automotive finishes, they have largely been supplanted in recent years with new high-melamine non-oxidizing alkyds. The latter, together with new acrylic resins, pave the way for future growth in automobile color ranges.

Due to their excellent electrical properties, alkyd molding compounds are being used in automotive spark plug nipples, coil towers, connectors and radio parts. They are receiving increasing attention for such other

This paper is a condensation of an article published in *Automotive Industries*, July and August, 1958.

TYPICAL PLASTICS PARTS FOR AUTOMOBILES

FUEL SYSTEM

Nylon
- Carburetor Accelerator Cam
- Carburetor Fast Idle Cam
- Tubing for Fuel Lines
- Gas Gauge Float Spacer

Fluorocarbons
- Carburetor Throttle Valve Bearings

Phenolics
- Carburetor Parts
- Fuel Injection System Parts

TRANSMISSION

Nylon
- Speedometer Driving Gear
- Speedometer Take-Off Gear
- Clutch Pedal Bushing
- Clutch Linkage Bushing

Fluorocarbons
- Diaphragm for Transmission Switch
- Bearing for Clutch Lever

Phenolics
- Clutch Disks
- Oil Pump Gears

ENGINE

Nylon
- Oil Pan Drain Plug Gasket
- Tubing for Vacuum Spark Line

Fluorocarbons
- Thermostats
- Valve Seats and Seals

Phenolics
- Water Pumps
- Radiator Strainers

BODY

Acrylic
- Fender Guide Light
- Decorative Medallions
- Hood Ornaments
- Reflectors

Nylon
- Window Regulator Gear
- Window Crank Knob Bushing
- Window Crank Hand e Bearing Plate
- Window Regulator Rollers
- Window Regulator Anti-Rattle Plate
- Window Slides
- Lock Control Bushing
- Door Hinge Bushing
- Door Weatherstrip Flipper
- Front Seat Back Stop
- Door Check Slide Block
- Door Latch Wedge
- Trunk Latch Wedge
- Tubing for Pneumatic Winaow Regulators

Polyethylene
- Film for Water Barriers
- Temporary Seat Covers
- Temporary Convertible Top Covers
- Floor Mat Fasteners
- Body Hole Plugs

Polyester Film
- Upholstery
- Door Panels
- Kick Plates
- Welting
- Exterior Trim

Acetate & Butyrate
- Moldings
- Handles and Knobs
- Steering Wheels
- Arm Rests
- Buttons
- Bezels

Copolymers
- Wheel House Covers
- Seat Backs
- Seat Side Panels
- Crash Panels
- Headlining
- Pillar Covers

Reinforced Plastics
- Car Bodies
- Seat Frames
- Car Tops
- Instrument Panels
- Convertible Top Covers
- Hoods
- Fender Fins
- Window Frames
- Station Wagon Rails
- Arm Rests

Vinyls
- Upholstery
- Scuff Pads
- Crash Pads
- Socket Seals
- Flexible Glazing
- Door Panels
- Arm Rest Padding
- Water Proofing
- Door Bumpers
- Glass Seals
- Mirror Backing
- Instrument Panel and Dashboard Covering
- Headlining
- Sun Visors

Polyvinyl Butyral
- Safety Glass Interlayer

Phenolics
- Water Proofing
- Plated Parts
- Insulation

ELECTRICAL SYSTEM

Nylon
- Fuse Holders
- Dome Lamp Lenses
- Sealed Beam Unit Lock Nuts
- Lamp Sockets
- Solenoid Insulators
- Generator Insulators
- Fuse Block Covers
- Push Button Covers
- Starter Motor Insulator
- Rotor for Headlight Foot Dimmer
- Horn Ring Insulators
- Motor Commutator End Plate
- Distributor Plate Separator
- Distributor Cable Holder
- Retainer Rings
- Courtesy Light Switch Housings
- Wire Clips and Connectors
- Push-Button Control-Collector Rings
- Push-Button Control Contact Cams
- Voltage Regulator Bases
- Window Regulator Switch Handle
- Switch Control Cam
- Radio Touch-Tuning Bar

Polyethylene
- Lamp Socket Spacer
- Cable Clamps
- Wire Insulation

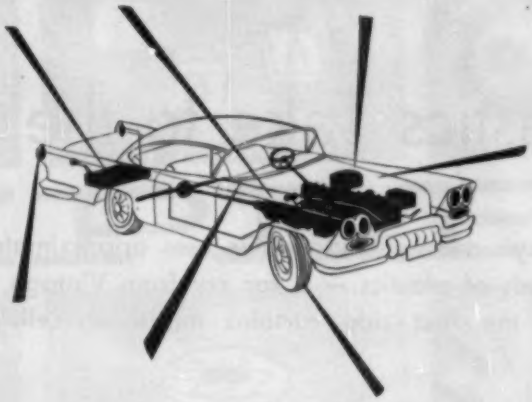
Acrylic
- Lenses, Dials and Pointers
- Exterior Lenses
- Control Knobs

Acetate & Butyrate
- Control Knobs
- Connectors
- Dial Pointers
- Tail Light Lenses

Copolymers
- Radio Speaker Grilles
- Connectors
- Battery Hold-Downs, Caps and Spacers

Phenolics
- Distributor Caps
- Coil Tops
- Rotors
- Connectors
- Insulators
- Printed Circuits

Vinyls
- Wire Coverings
- Spark Plug Nipples
- Insulators



ACCESSORIES

Nylon
- Windshield Wiper Cam
- Windshield Wiper Gear
- Speedometer Worm Gears
- Heater Control Slide Bushing
- Heater Control Linkage
- Mirror Socket Bushing
- Mirror Flipper
- Windshield Washer Valve
- Windshield Washer T-Connection
- Rod and Gear for Antenna Elevating Device

Acrylic
- Traffic Light View Lens
- Sun Visors

Fluorocarbons
- Thrust Bearings on Speed Controller

Polyester
- Heater and Air Conditioner Housings

RUNNING GEAR

Nylon
- Brake Pedal Bushing
- Brake Hub Spring Insulator Bushing
- Brake Linkage Bushing
- Master Brake Cylinder Push Rod Bushing
- Center Link Bushing
- Upper Steering Column Bushing
- Tire Valve Caps
- Tubing for Automatic Lubrication Systems
- Tubing for Air Suspension Systems
- Air Suspension Levelling Valve Components

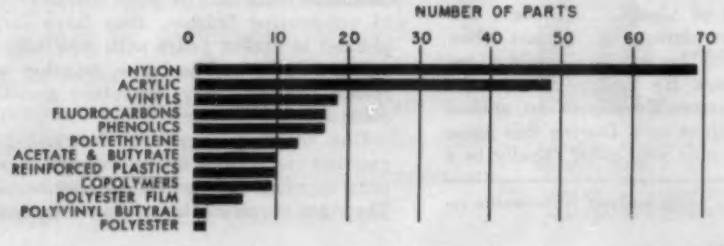
Fluorocarbons
- Shaft Seals for Power Steering
- Piston Ring for Power Steering
- Gasket on Lock Nut for Power Steering
- Gasket for Power Steering Unit Assembly
- Additive in Grease, Ball Joints

Polyethylene
- Spring Liners
- Ball Joint Dust Cover

Vinyls
- Valve Caps

Phenolics
- Brake Linings

DISTRIBUTION OF PLASTICS
(APPROX. 220 PARTS)



electrical applications as distributor caps and rotors. Although the phenolics continue as the dominant plastics material for these uses, the alkyds are gaining ground in spite of the higher volume price they demand.

Epoxies

Introduced just a few years ago, the epoxies are among the newest of the large-volume plastics. Since they set at low temperatures and bond a large number of materials easily, the epoxies have won ready acceptance for adhesives used in automotive and other applications. Their wide range of properties has also made them popular for use in foams, casting compositions, caulking and repair compounds, body solders, and as patching and sealing materials. Epoxy resin laminates are well suited for use in laminated tooling, printed circuits and as structural members for aircraft. Plastics tooling has grown by leaps and bounds through development of epoxy resin formulations that have successfully overcome many of the problems encountered with other resins.

The flexibility, adhesion and moisture resistance which the epoxies offer assure them of a bright future in automotive finishes and an excellent potential in protective coatings for exterior brightwork.

Melamines

Adhesives and finishes are two important automotive applications for melamine resins. Melamine molding compounds are employed in automotive ignition parts because of their good dimensional stability and dielectric strength.

Phenolics

Without the phenolics or a comparable material, the automobile would not be what it is today. Affectionately referred to as the "workhorses" of the electrical system, phenolics are used in distributor caps, coil tops, rotors fuse retainers, wire connectors, terminal blocks and laminated insulators. Printed circuits on phenolic laminates are receiving much attention from automotive electrical engineers.

Reinforced phenolics are gaining a decided foothold in the automobile industry. Chrysler, for example, uses

Figure 1. Metalized Mylar polyester film is used for gold fender fin inserts on the 1958 Packard Hawk.

a transmission oil pump gear made of phenolic-glass molding material, and Ford is said to have a number of development molds in the works. Detroit Transmission is using a reverse cone clutch ring made of the same material.

Phenolic parts are also being used in fuel injection systems, carburetor elements, clutch discs, water pump impellers, thrust washers and brake handles. There is a possibility that chrome-plated phenolic parts may eventually replace plated die castings to eliminate corrosion and reduce weight.

The phenolic resins, which are used as binders in the molding compounds, are also employed as impregnants, adhesives and binders in other automotive parts. Foremost among these is the manufacture of brake linings, in which modified phenolic resins are used in combination with asbestos fibers and other friction materials in a mixture containing about 25 percent resin. Phenolic resins are likewise used as binders in impregnated glass-fiber-reinforced insulation batting, employed as insulation barriers in car door and body panels, and under the hood. Other uses for phenolic resins include impregnants for air and oil filter parts and in protective coatings.

Polyesters

Premix materials constitute one of the fastest growing segments of the polyester field at the present time. Major end uses in the automobile industry are heater

Figure 2. This instrument panel for several Studebaker-Packard cars is produced by Molded Fiber Glass Body Co. Golden Hawk panel is covered with crash pad; others are painted. Glove compartment is molded right into panel.

Figure 3. Window washer reservoir on Corvette is Hi-fax polyethylene.

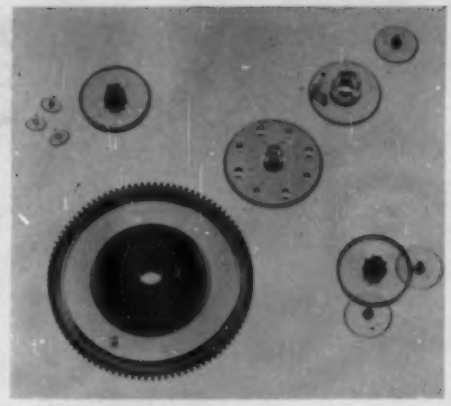


Figure 4. These gears are Lexan polycarbonate. Some gear, pinion and shaft assemblies are molded in one piece.

Figure 5. De Soto tail lights, made of Lucite acrylic, are visible for great distances.

and air conditioner housings and ducts, window frames, truck transmission housing covers and grille protectors. The polyester resins, reinforced with either glass or sisal fibers, will find increasing usage in engine, body, electrical and trim parts.

[Reinforced polyesters lend themselves to limited production items like the Chevrolet Corvette body. Since expensive dies are not needed, initial cost of the car is held within reason, and yearly restyling is economically feasible even though production volume is small. The success of the Corvette's plastics body has been borne out by several foreign automobile manufacturers now making bodies from reinforced polyester and by the many "specials" which continue to appear on our roads and race courses.]

The automobile industry is adding new applications of reinforced plastics with each model change. Their current uses include: heater and air conditioner housings and fresh air ducts on the Chevrolet, Dodge, Plymouth and Chrysler; arm rests on the Lincoln; fenders on the Willys Jeep; convertible top boot on the Cadillac; hood and front grille on some Studebaker-Packard models; hardtop on the Ford Thunderbird; station wagon rails on Ford, Mercury and Edsel.

Truck manufacturers are also moving more and more into reinforced plastics for grilles, cabs and trailer bodies. For example, Molded Fiber Glass Body Co. of Ashtabula, Ohio, is currently making parts and assemblies for several trucks, as well as for eleven different passenger cars. The company will shortly start delivering complete truck cabs made of reinforced plastics. Potential applications for reinforced plastics in the trucking industry are viewed as very promising because of the important savings in weight offered.

Silicones

Silicones in one form or another are used by: vehicle and accessory manufacturers; producers of materials for automobiles and accessories; maintenance and repair shops; and car owners themselves. Damping and shock-absorbent devices are obvious uses for silicone fluids, while silicone-base paints are used on automobile engine manifolds and exhaust pipes.

Silicone additives are used in compounded motor oils and antifreeze to prevent foaming and in the manufacture of foamable materials; they are also used to improve the mar resistance of paints. As manufacturing aids, silicones are used in release, damping, sealing and other applications.

Ureas

Urea-formaldehyde resins are widely used as adhesives and in surface coatings. Most familiar automotive applications are knobs or buttons for radios and other equipment. One car manufacturer is considering a urea ring for a nylon dome light lens.

THERMOPLASTICS

Acrylics

The acrylics are found primarily in the body, electrical system and accessories of the modern car. They are used extensively for both interior and exterior decorative and functional purposes. Molded easily in various shapes and sizes, acrylic has become the standard material for tail light lenses. Other electrical system uses include parking lights, directional signal lights and back-up light lenses. Instrument lenses are made of the material, and it is used for edgelighting and for piping light. Acrylic lacquers are continuing to gain in popularity for automotive finishes.

Hood and horn button medallions, control knob rings, instrument panels and door liners typify other applications for the material. First-surface metalized acrylic, for example, is used in the 1958 Ford car instrument panel and hood medallion and the Ford tractor hood medallion. It is also being used in the 1958 Imperial for door liner panels and in decorative form on the instrument panel background.

The first significant application of first-surface metalized acrylic was in the 1957 Ford speedometer dial. The 1958 version of this part is even larger in size. By way of contrast, second-surface metalizing (from the back of the part) has been used for many years. This is part of the process used to achieve a three-dimensional effect in dials, lenses, bezels and medallions.

Cellulosics

The first significant application of plastics in the automobile industry was the use of cellulose nitrate in side

curtains back in the early 1900's. After the advent of the closed car, this material was subsequently used in sheet form as an interlayer for safety glass. However, it was soon supplanted in this application by cellulose acetate which, in turn, gave way to polyvinyl butyral. While cellulose nitrate is tough and cheap, it is inflammable and cannot be injection molded.

Cellulose acetate has been used widely for interior decorative trim and all types of knobs and buttons. A newer use is in automotive air conditioner parts.

Cellulose acetate butyrate's automotive applications include: steering wheels, arm rest bases, interior knobs, headliner bows, escutcheons, seat hinge covers, brake lever handles, instrument panel lenses and other panel parts. A new application is for a sun visor on the 1958 Lincoln. Tail light lenses of the material are used on the 1958 Oldsmobile.

Cellulose propionate is the newest of the commercial plastics. Its automotive applications are similar to those for butyrate: moldings, steering wheels, control knobs and arm rests.

Fluorocarbons

Of the fluorocarbons, polytetrafluoroethylene is by far the most widely used in today's automobiles. At high loads this material has the lowest coefficient of static friction of any bearing surface. This particular property makes it useful in such automotive mechanical parts as clutch pedal bushings, brake systems, transmission seals, power steering and suspension systems.

Filled Teflon and reinforced constructions are winning increased attention from the automotive designer as bearing materials because of their ability to carry high loads. Teflon is also finding applications in: clutch lever bearings; thrust bearings for seat adjusters, door locks, speed control devices and transmissions; bearings for diesel engine governors; odometer bearings; bearings for bus door controllers; universal joint bearings; and sleeve bearings in carburetors.

Other current and potential applications include: power steering shaft seals, piston ring and locknut; thermostat valve seats or seals for GM cars; diaphragm for transmission switch on Mercury; air suspension throttle valve; piston seal for fuel injectors; ignition wire insulation; engine piston rings; valve stem seals; and coatings on window channels and weatherstrippings.

Figure 6. Grommet-like part on Edsel steering column is molded of Geon plastisol and foam to cut vibration.

Figure 7. One-piece distributor cap, injection molded from Montacatini's polypropylene, cuts production costs.

Nylons

The first functional automotive application for nylon was in dome light lenses, where its heat resistance, toughness and ability to withstand discoloration are important. It is estimated that since 1950 the use of nylon in passenger cars has increased by over 700 percent.

The toughness and low friction characteristics of nylon make it popular for such applications as door latch wedges; front-seat back stops in two-door models; gears for windshield wipers; clutch cross-shaft bearings; spring interliners; brake pedal bushings; window crank handle bearing plates and regulator rollers.

The good electrical properties of nylon account for its widespread usage in connectors, fuse holders, instrument lamp bases, horn switch insulators, coil forms and miscellaneous parts for small motors.

One of the most interesting functional applications of nylon is in speedometer pinion gears. Offering smooth, quiet operation, the nylon parts do not require the close tolerances reequired for steel gears. Although at first nylon was used only in the gear, it is now used to make the pinion shaft also.

Flexible nylon tubing is used for centralized pressure lubricating systems, fuel lines, flexible shaft housings and pneumatic lines for shock absorber systems.

A partial list of other nylon applications would include such functional parts as: accelerator bushings, air conditioner ducts and grilles, speedometer take-off gears, ball joint suspension bushings, carburetor parts, hardware (both inside and outside), fuel pump and filter parts, distributor rubbing blocks, tire valve caps, brake camshaft bearings, steering bushings and thrust washers.

Polyethylenes

Until recent years, polyethylene was used primarily as a film to protect seat and door trim panels in trans-

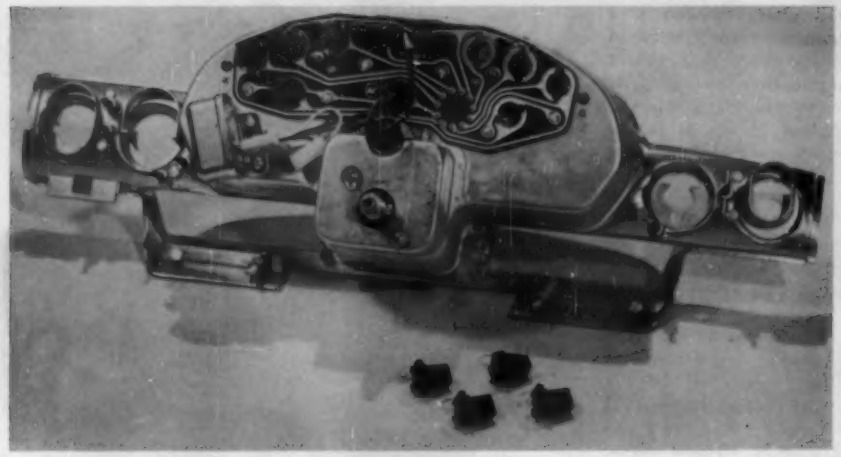


Figure 8. The printed circuit plate used in the Oldsmobile is molded from phenolic. The lamp sockets for the panel are nylon.

it and as a cover for cars during storage on open decks of ships. Currently, however, many practical uses are being found for molded polyethylene and film.

Film is used as a water shield between the door foundation board and inner door panel. Molded polyethylene has been used successfully as a full length spring interliner and is currently found also in storage battery caps, ball joint dust covers and wiring insulation. Other applications include floor mat fasteners, lamp socket spacers and cable clamps.

A current application of the new high-density polyethylenes is the reservoir of the window washer on the 1958 Corvette. A number of other applications are under evaluation for 1959 cars, including: air conditioner, heater and air ducts; battery parts; instrument panel; gas tank air vent and float inlet; sun visor; window channels; spring-leaf inserts and liners; and radiator overflow tubes.

Polystyrenes

Styrene polymers and copolymers are beginning to enjoy real success in the automobile industry. Present applications include battery caps, spacers and hold-downs; air conditioner housings; windshield wiper mechanism parts; crash pads; headliners; kick pads; piller post covers; electrical components; condenser housings; radio speaker grilles; knobs; escutcheons; and line connectors.

Applications under consideration include: arm rests, horn housings, push buttons, switch housings, trickle valves, switch cams, steering wheels, speedometer and ignition housings, battery cases, windshield washers, light lenses, bumper seat-stops, seat hinge covers and window bearings.

Vinyls

One of the first and most widely known plastics in the automotive field is polyvinyl butyral which is universally used in the manufacture of safety glass.

Vinyl sheeting, vinyl-coated fabrics, films and related materials are being used to make interiors more beautiful, more serviceable and easier to clean. Seating, door panels and side wall areas, arm rests, headlinings, scuff pads, instrument panel coverings and sun visors typify the many applications of vinyls in the car of today.

Vinyl laminates on sandwiches of cotton backing and rubber have become popular convertible deck materials, while certain imitation carpet facings are constructed from vinyl-coated burlap or jute.

Perforation of coated sheeting permits the use of vinyl as a headlining material. Transparent polyvinyl chloride sheeting finds widespread application in convertible rear windows and in the aftermarket for transparent seat covers. Vinyl sheeting is also used in the 1958 Ford and Mercury for door panels, in the Buick, Chevrolet, Ford, Edsel and Chrysler as crash pad coverings, and on certain models as upholstery material.

Many manufacturers use a layer of vinyl sheeting over the metal dashboard and instrument panel to provide a non-marring, non-reflective surface. The 1958 Thunderbird is a good example of the use of vinyl-to-metal on the transmission housing, certain areas of the doors, dashboard, and as a crash pad substitute. Vinyl tape is used on some cars to back up the rear view mirror to prevent glass from flying out of the metal frame in a collision.

An interesting new use of vinyl foam is found on the Edsel where a grommet-like fixture around the steering column is one piece of chemically blown foam covered with a plastisol skin.

The vinyls are at home on the exterior of the car and under the hood as well as inside. Typical molded or extruded parts are window weatherstrips, spark plug nipples, battery and radiator drain tubes and wire coverings. Increased usage can be expected.

Closely associated with the vinyls are the vinylidene chlorides known as saran. As an extrusion, saran is used as a seam welt filler for upholstery. A relatively new usage is a gasoline filter made from woven saran cloth.

Conclusion

Plastics have made giant strides in the automobile industry because of their inherent potential for variety of form, color, texture and ease of application. Due to their ability to replace complex and expensive assemblies with simple molded units, they have contributed important cost savings in the manufacturing process. There is every reason to believe that the car of tomorrow will contain many new and fascinating decorative and functional plastics parts.

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Vacuum Metalizing in the Automotive Industry

A sufficient number of applications are presently used by the automotive industry to indicate that first surface vacuum metalized finishes could be used for numerous interior trim parts which are now chrome plated or painted.

William Pahl
Manufacturing Research Engineer
Ford Motor Company

VACUUM METALIZING is a process whereby a bright metallic film is condensed on a surface of an object in a vacuum. This object can be made of glass, metal, plastics or a number of other materials. When the metallic film is condensed on the back side of an object made of a clear materials and is viewed through the material, the process is called *second* surface vacuum metalizing. When the metallic film is condensed on the outer or primary surface of an object, the process is referred to as *first* surface vacuum metalizing. Second surface metalizing has been used by the automotive industry for many years, both on interior and exterior trim parts. The advantage is that the coating is protected by the overlay of clear material from wear, abrasion and atmospheric elements. The moldings must be of a material that is water clear and has good light stability.

This discussion deals mainly with first surface metalizing of molded plastics parts.

First surface application permits the use of a variety of opaque plastics, metal stampings, die castings and certain other materials. The engineer now has at his disposal numerous materials with a wide range of physical properties from which to make his selection for designing interior trim parts.

In the automotive field, plastics are playing a much greater role today than they did even a few years back. This is primarily due to the development of new plastics with better physical properties such as higher heat resistance, greater strength and better color stability. Another important factor contributing to the increased use of plastics, especially in the automotive field, is the development of more durable metalized finishes. This permits, in many cases, the replacement of chrome plated metal parts by first surface vacuum metalized molded plastics parts. The concerns formulating and supplying the organic coatings are constantly striving to develop tougher and more durable coatings. There is no doubt that the materials available today are far superior to those of only a few years ago. In addition, the metalizing industry has grown and kept pace with the demands of the automotive concerns and is capable of large volume finishing.

The Ford Motor Co. has used first surface vacuum metalizing for certain interior trim parts for the past two years. To the best of our knowledge, Ford was the pioneer in this field. In 1956, at the beginning of production of the '57 model Ford passenger cars, first surface metalizing was used on the main instrument cluster and odometer dials, and on the clock, heater and radio instrument panel opening covers. The main instrument cluster and the odometer dials were one-piece moldings of acrylic. The bezel area of these parts was metalized. The window section was masked to prevent the deposition of aluminum and base and top coat materials on the area. When the finishing process was completed, what appeared to be a glass window with a chrome plated steel bezel was obtained. The letters and numerals were molded in the back side of the window section and were then paint filled and wiped. This one-piece molding replaced an assembly of two chrome plated steel stampings, a glass disc and a rubber gasket. When consideration is given to tooling, processing, material and assembly costs involved in the metal, glass and rubber assembly, it is quite apparent that substantial savings were effected with metalized plastics. In addition to cost savings, a hazard was eliminated by replacing glass with clear plastics. Covers for the clock, heater and radio openings in the instrument panel were molded of an acrylonitrile modified styrene which has good flexural and impact strength, along with a fairly high minimum heat distortion temperature. These covers were bright finished by vacuum metalizing where previously they were painted to match the color of the instrument panel. There was no direct cost savings, but a more attractive instrument panel was produced.

In our opinion, Ford was the first in the industry to take advantage of first surface metalizing of a molded thermosetting plastics part. Until May, 1957, the dome lamp housing in Ford passenger cars was a chrome plated zinc die cast part. Specifications for this part required that the material used withstand 400°F or over. This naturally eliminated the more common thermoplastics and some of the thermosetting materials. Efforts were concentrated on a heat resistant phenolic. Experimental parts were molded of various materials in a single cavity mold. These were then base coated, metalized, top coated and subjected to accelerated tests to determine how the coating and the molding would react to the finishing process and the subsequent testing. A number of the phenolic compounds were eliminated due to surface texture in the molded part.

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Others were eliminated due to the formation of an iridescence in the coating during the top coat curing cycle or in the accelerated cycle test. The best results were obtained with an asbestos filled phenolic compound. Parts molded of this compound produced a smooth high gloss surface and lent themselves well to bright finishing by the metalizing process. Good adhesion and brilliance of the coatings was obtained. However, one problem encountered with this material was a relatively short mold life. But, with the cooperation of the manufacturer of the phenolic molding compound, a suitable material was developed which has increased the mold life considerably.

In this case a chrome plated zinc die cast part weighing 6 ounces was replaced with a 2-ounce metalized phenolic molding at a substantial cost reduction. Appearance-wise, the metalized molding is superior to the plated die-cast part. It is not intended to imply that a first surface metalized finish is superior in all respects to a chrome plate finish. Certainly a good chrome plate finish has better abrasion and wear properties than a vacuum metalized surface which is dependent upon an organic film for its durability. However, this part and those mentioned previously, serve a decorative purpose, mainly, and are not subjected to excessive wear or abrasion. They have served this purpose well.

These applications are typical of first surface vacuum metalizing in the automotive field. There are numerous similar applications by the industry on current model cars.

The three major steps in applying a first surface metalized finish to a plastics part are listed here in an effort to point out the important role played by the stylist and the design engineer in the overall picture:

1. The application of the base coat to provide adhesion and a high gloss surface as a base for the metallic film.

2. The deposition of the metallic film in a vacuum of ½ micron or less.

3. The application of a clear top coat if the finish is to simulate chrome plate, or a tinted top coat if a transparent metallic color tint is desired. The top coat is a protective coating for the metallic film which is roughly 3 to 5 millionths of an inch in thickness.

In each of the above operations it is important that the parts do not touch each other in the area that is to be coated; otherwise surface contamination, scratching or dirt pickup will result. Therefore, it is necessary to fasten each individual part securely to a rack or fixture so it will remain in the desired position throughout the processing period. It is necessary to incorporate in the design of the part some means of holding it on the rack with a clip or other fastening device. The ease with which the parts can be loaded and unloaded from the fixture will be reflected in the overall processing cost.

The application of the base coat and a clear top coat can be accomplished by either manual or automatic spray, dip or flow coating methods. If the top coat is of the colored type, then it will have to be applied by spray method since it is questionable whether color uniformity can be obtained by dip or flow coat methods. The method selected for applying the coatings will be determined by the shape, size and other physical characteristics of the part. It is here that the design of the part becomes an important factor. Deep recesses, sharp edges and large unbroken flat surfaces should be avoided whenever possible. Parts with deep recessed areas are difficult to spray, and also present a problem in dipping or flow coating if excess material cannot be drained off. When the design of the part permits processing of completely loaded racks or fixtures through the entire finishing system, then it approaches the most economical means of applying the first surface metallized finish.

If only certain areas of the part are to be bright finished, then masking is required to shield the area to be left uncoated. Coatings are usually applied to these parts by spraying each part individually on an automatic spray machine equipped with appropriate masks. It is advisable to have a step, recessed groove or ledge molded in the part to facilitate masking and to produce a sharp line of demarcation between the coated and uncoated areas. It is quite obvious that finishing cost will be considerably higher for parts that require masking.

This discussion cannot include the coating systems for all of the various types of plastics. It can be stated that in finishing plastics parts, especially the thermoplastic types, it is important that the base and top coat materials used have been formulated for the specific plastics. A material that may work well on a crystal grade of polystyrene may not be the best type for high-impact or acrylonitrile modified styrene. The lacquer suppliers have spent much time in formulating coatings for the various types of plastics and they are much better qualified to provide this information.

In order to have some assurance that the finished parts would perform satisfactorily in service, some accelerated tests had to be developed. There were no standards or test procedures set up for first surface metalized finishes. The specifications and test procedures developed by Ford for this purpose consist of tests for adhesion of the coatings, for resistance of the coatings to blistering, peeling, discoloration and loss of luster when subjected to a moisture and salt laden atmosphere, and to ultraviolet radiation.

One accelerated test consists of exposing the finished part to the following:

8 hours salt spray as per ASTM Standard B-117
6 hours high humidity at 110°F
4 hours sunlight exposure at 150°F
6 hours high humidity at 110°F

This constitutes one cycle; our specifications stipulate that the color, adhesion and luster of the finish on the test part shall not be appreciably affected after completion of five cycles. We feel quite certain that a finish which passes this test will perform satisfactorily on trim parts which are not subjected to excessive wear and abrasion in service.

Although at present the use of first surface metalized finishes in the automotive industry is not extensive, a sufficient number of applications have been and are being used today to indicate that the finish has proven itself. There are numerous interior trim parts which are now chrome plated or painted that could be replaced adequately by a vacuum metalized finish. In many instances steel stampings and die castings could be replaced by vacuum metalized plastics moldings at considerable savings in material as well as processing and finishing costs. Another important fact which we believe will increase the use of metalized finishes on plastics as well as on metal parts is the potential that color metalized finishes offer to the stylist. Practically any desired color tint can be had in this type of finish with only a slight increase, if any, in cost over the simulated bright chrome. It is not unreasonable to assume that in the future the chemist will develop plastics materials with still better properties than those now available, and that the coating suppliers may develop coatings so durable that first surface metalized finishes can be used for exterior automotive trim parts.

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Designing Plastics Lenses for Cars

The constant development of new plastics materials and techniques has enabled the automotive engineers and stylists to make great strides in designing lighting equipment with increased safety features.

August Meyer, Jr.
The Electric Auto-Lite Co.

LIGHTING EQUIPMENT must first receive state approval before it can be legally sold or used on a motor vehicle in most states. To obtain state approval, the lamp manufacturer is generally required to provide evidence in the form of an independent laboratory test report that the design and performance specifications of the equipment comply with appropriate minimum standards for such equipment; i.e., those standards recommended by the Society of Automotive Engineers. Also, in some states, the submission of lamp samples and a prescribed fee is required.

Much progress has been made in the last ten years in the automotive lighting field. Credit for these improvements goes to the plastics industry as well as to the automotive industry as a whole. In the automotive industry, we have the Vehicle Lighting Committee and Lamp Manufacturers Sub-Committee as part of the Automobile Manufacturers Association. The Lighting Committee of the SAE consists of various sub-committees. One of particular note is Plastics Used in Lenses for Motor Vehicle Lights and for Reflex Reflectors Sub-Committee. This sub-committee has been playing an important part in determining recommended practices involving types, colors and grades of materials along with outdoor exposure and heat tests for products involved in automotive lamps.

There is also the American Association of Motor Vehicle Administrators who perform their functions very favorably. They represent the states in matters of law, and interpret the Uniform Vehicle Code of the National Highways Users Conference. They, and the other committees, including other professional and non-professional help, have all contributed to progress attained.

With the advent of the turnpikes and freeways, a need for improved lighting was very apparent. The ever-increasing number of motor vehicles which are capable of higher speeds makes the problem more urgent. As a result of many traffic accidents due to higher car speeds, the State Commissioners asked for help.

This paper was presented at the SPE Regional Technical Conference in Detroit, September 12.

Through the help and cooperation of the various committees mentioned, the use of plastics lenses came into being. This brought about a substantial price increase in lenses at the start—about 3 to 1 depending on size.

With increasingly rigid lighting specifications, along with size, shape and other limiting factors, further improvements in glass lenses left much to be desired.

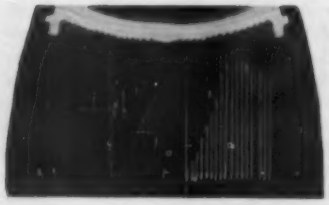
With the swing to plastics lenses, a new era in lighting began. We soon realized, for example, that the wide range of color temperature variation would be reduced tremendously. Thinner wall sections could be used, reducing light absorption factors and utilizing the light source more efficiently. Precision tooling involved in injection molds, by comparison to cast iron molds used in making glass lenses, gave us new liberties in designing optical systems. A lighting device must comply with certain specifications which include photometric requirements, and must, therefore, include an optical system. Optics, as we speak of it, is a system incorporated into a lens to control the light output. Several types of optical systems commonly used are discussed here.

Dioptric Prisms

Dioptric prisms are prisms which refract light rays only. As a rule, dioptric prisms are very efficient and can be designed for fairly good control of light. In this type of optic, light rays originating at the light source impinge on the optic surface of the prism and are refracted into the material. These refracted rays travel through the material to the front face where they are then refracted out. By controlling the angle and shape of the optic surface of the prism where the rays first impinge, the direction and intensity of the light rays emitted from the material can be controlled.

Catoptric Prisms

Catoptric prisms are prisms which reflect light rays only. These prisms have little use in lens optic designing since light must pass through the lens material. Catop-



DODBK

TWO SHOT TWO COLOR BACK-UP LENS.

HUHA

COMBINATION TAIL-STOP-TURN SIGNAL AND REFLEX LENS.

trics, however, are important if a reflector is included in the optical system.

Catadioptric Prisms

Catadioptric prisms are prisms which involve both the refraction and reflection of light. As a rule, catadioptrics are not as efficient and do not permit as accurate control of light as dioptric prisms. However, they are very important in lens optic designs; they have greater versatility than the dioptrics since they are less affected by limiting and critical angles and may be used where dioptrics would be completely inaffective.

Reflex Reflectors

Reflex reflectors are an optical system in which a light source is projected into the external face of a lens or unit surface, impinges the material to an inner face where it is reflected to a secondary inner face and again reflected back through the original external face. The primary object in this type of unit is to light an object or vehicle which is not employing any light source of its own, but rather, by an oncoming vehicle having light sources such as headlamps. For many years, this type of reflex has been used in individual button types.

Other Developments

In 1951, we made our first tail lamp plastics lenses with tail, stop, turn signal *and* reflex characteristics included. This was involved in a lamp known as "HUHA."

There were specialists in the plastics field then who said it wouldn't work. To my best recollection, this lens was a first. Successfully producing combined optic systems outlined previously along with reflex characteristics required new cycling and molding techniques. Today Ford is still one of the few manufacturers of this type product which can meet automotive standards.

Another volume-production first is the so-called two-shot, two-color lens. This was first accomplished by using a complete optical system in a crystal plastics portion surrounded by ruby plastics. For identification it was used in a lamp known as "DODBK."

Automobile designers have been limited in their treatment of lamps on automobiles over the years. In this decade, however, they have obtained new liberties with the use of plastics. Most of us will gladly agree that the car stylists have been and are now playing a very important part in the progress of design improvements. Many of us have worked with the stylists, aiding them in realizing their ambitions. Good sound engineering practices, along with practical experience, have helped bring about the modern styling advances. We can give such examples as metalized acrylic plastics serving as trim bezels on lamps, and uses of such trim bezels in conjunction with optical lens features combined in one piece. Decorative ornamentation features, which enhance the beauty of the car without destroying the fundamental purpose of the lamps, have been a great accomplishment.

The constant development of new plastics materials and techniques has enabled the automotive engineers and stylists to make great strides in designing lighting equipment with increased safety features. Further cooperation between the plastics engineer and the automotive engineer will assure continuing progress in this line.

Polymerization with Radiation

A critical evaluation of the application of ionizing radiation in polymerization, cross-linking and graft copolymerization with respect to economics; advantages and disadvantages as compared with conventional chemical methods; and feasibility in terms of available sources, radiation damage, shielding and uniformity of radiation dose.

Part II—Technological Considerations

Robert McFedries

The Dow Chemical Co.

Part II

This is the second and final part of a paper presented at the Fourteenth Annual Technical Conference of SPE. Part I, General Considerations by R. F. Boyer, appeared in the September issue of the SPE Journal.—editor.

LET US EXAMINE the significance of these new processes and techniques to the plastics industry. Although research has been proceeding at a rapid pace in this field, the actual number of applications of radiation to volume production have been relatively few. In radiation application in general the interest in the development of process applications for high energy radiation has been encouraged by the proposals and sketches of Manowitz (Ref. 32), and others (Refs. 2, 33), and pioneered by General Electric, Sequoia and Ray-Therm. Although these present processes market products that find rather specialized applications in the electrical field, it would seem reasonable to predict that the use of radiation as a processing tool will soon find much broader application in the plastics field.

In the field of food irradiation, it appears that such a break-through is beginning with the construction of the Army ionizing radiation center. In this center actual production lines are being installed for food irradiation. Already certain foods have been approved for this treatment. Such a process could soon move radiation facilities into the plants of every major food processor in the country. It appears just as likely that the somewhat restricted application of high energy radiation in the plastics industry will soon reach the point where the development of materials designed specifically for radiation processing will result in the same widespread use of radiation equipment in plastics plants.

These are the questions one should ask when a problem arises which might be solved by the proper application of high energy radiation:

1. How much radiation is necessary?
2. How rapidly can the radiation be applied?
3. How much variation in the dose can be tolerated in each part and between parts?

With these questions answered, one should be able to determine if the advantages gained in the processing are valuable enough to make the process economically sound. (It should be understood that these comments are concerned only with the irradiation step in the process; prior or subsequent steps in the process can, naturally, prove inefficient and eliminate the economic application of the process.)

Total Dose

The question of "How much?" will be determined primarily by the chemical structure of the polymer and the effect desired. Table IV illustrates the importance of chemical structure in determining total dose.

It may be proper at this point to define the terms used in Table IV. A "rad" is a measure of absorbed radiation and is defined as 100 ergs of absorbed energy per gram of material. The term "Dosage to Produce 25% Damage" used in Table V is defined as the dosage at which at least one of the physical properties of the material has changed by 25% from its initial value.

It will be beneficial to examine the materials listed and present reasons put forth for their behavior (Refs. 34, 35). Notice that the materials exhibiting the highest resistance to radiation all contain a benzene ring in their structures. This co-called "resonant" configuration has the ability to "protect" a chemical system from radiation damage by distributing the energy in forms other than bond scission. Thus it takes large amounts of radiation to cause significant changes in polymers whose structure is dominated by a resonant group. Polyethylene, on the other hand, has no such group in its structure. The configuration of the molecule favors recombination of any cleaved carbon bonds and thus produces a certain amount of stability in the backbone chain. In addition, an abstracted hydrogen will produce an active site on the main chain which can further react with an adjacent chain to form a cross-link. The presence of a halogen in the polymer structure, as in vinyl-vinylidene chloride copolymer, causes a reduction in the stability of the material. The materials of this class exhibit severe discoloration at rela-

TABLE IV

Sensitivity of Polymers to High Energy Radiation*

Polymer	Total Dose To Produce 25% Damage (Megarads)
Polystyrene	>4000
Polyester	3900
Phenolic Asbestos Filled	890
Polyethylene	93
Vinyl-Vinylidene Chloride	45
Methyl Methacrylate	11
Polytetrafluoro-ethylene	0.037

*References 36, 37

tively low doses followed by degradation of physical properties. An alpha methyl substituent on a polymer will also cause the material to be unstable when subjected to high energy radiation. This behavior is attributed to the stability of the radicals formed by a main chain scission and the steric hinderance of the pendent groups. This effect is seen in the degradation of methyl methacrylate. The predominance of the instability caused by an alpha methyl group can be noted by comparison of polyalphamethylstyrene, which shows 25% damage at a dose of 43 megarads, and polystyrene. The protective effect of the resonant group, so evident in the polystyrene, is completely eliminated by the addition of an alpha methyl group to the structure. Polytetrafluoroethylene illustrates an extreme effect of halogens in that the relative bond strengths of the reactants and the products favor the scission of the carbon-carbon main chain bonds, rather than the carbon fluorine bonds, and thus the material degrades rapidly at relatively low doses.

A basic set of rules that can be remembered to relate chemical structure to the radiation sensitivity of the material are:

1. Resonant groups in a polymer structure tend to stabilize the system and make it insensitive to radiation (polystyrene and polystyrene copolymers).
2. Structures containing an alpha hydrogen in their structure tend to cross-link (polyethylene, polymethlacrylate).
3. An alpha methyl substituent will cause the polymer to degrade and increase its radiation sensitivity (polymethyl methacrylate, polyalphamethylstyrene).
4. Polymers containing halogens tend to degrade (polyvinylchloride, polyvinylidene chloride, polytetrafluorethylene).

There is a great deal of work being done at present on the use of various chemical additives to reduce or pervent radiation damage to organic substances. The main emphasis thus far has been on biological systems (Ref. 38), but there seems little doubt that chemical protectors against radiation will be found for most polymers. The future may well alter the degradative effects which seem to dominate the field of polymer-radiation interactions at the present time.

The effect desired is the second major factor in determining total dose. It can be seen from Table V that there can be an appreciable variation in dose to produce different effects in the same polymer system.

It is difficult to specify exact total doses because of the various degrees of an effect that may be desired and the complicating matter of dose rate effects in polymerization and grafting. It can be seen, however, that there is an appreciable variation in total dose, depending upon the effect desired.

The final answer to the question of how much radiation is needed should indicate if the project deserves further consideration. At present it would appear that the advantages of radiation may be worth a maximum additional cost of 20 to 30¢ a pound; therefore, if the cost of radiation to produce the desired effect is beyond this limit, the project can be dismissed.

Dose Rate

Concerning the second question of "How rapidly can the radiation be applied?" the problem is influenced by the configuration of the product, the heat build-up in the product and, again, the effect desired.

The problem of part configuration is brought about by the penetration characteristics of the radiation. Accelerated electrons are characterized by high dose rates (in the range of megarads/minute) and penetration of fractions of an inch in unit density material while gamma sources have lower dose rates (in the range of

TABLE V

Radiation Dose Required for Cross-Linking, Graft Copolymerization, Polymerization and Degradation

Polymer	Effects (Dosage in Megarad)			
	Cross-Link	Graft	Polymerization	Degradation
Polyethylene	5-25	1-3	5-7	80-150
Polystyrene	100+	1-3	10-1000	4000
Polyvinyl Chloride	0.1-0.5	0.05-0.02	0.2-5	1-100

TABLE VI

Dose Rate	% Graft	% Homopolymer
0.5 Mrad/hr.	10-20	80-90
20 Mrad/hr.	80-90	10-20

TABLE VII

Dose Rate	Total Dose	Condition of Polymer
0.35 Mrad/min.	2 Mrad	Room Temperature
0.60 Mrad/min.	2 Mrad	Very Warm
1.50 Mrad/min.	2 Mrad	Hot

megarads/hour) and deep penetration. With this in mind, it is evident that parts with thick cross-section or unusual configuration would necessitate the use of gamma sources and their accompanying low dose rates. On the other hand, products such as films, tapes and coated wire, which are relatively thin and of simple geometry, can be efficiently irradiated with the higher dose rate electrons.

As in the case of total dose, the effect desired will influence the choice of dose rate. It has been indicated in Table I that the dose rate has a profound effect on radiation induced polymerizations. The effect is compounded in the case of graft polymerization by the competing reaction of homopolymer production. This is illustrated by Table VI (Ref. 39).

It can be seen from Table VI that an improper choice of dose rate can have a drastic effect on product composition.

In the case of cross-linking, dose rate appears to influence the product only in the presence of oxygen. A low dose rate allows oxygen diffusion and peroxide formation, whereas at higher dose rates reaction between active sites is accomplished before the oxygen is able to diffuse to the site.

The ultimate dose rate will be determined by the heat build-up in the exposed material. For example, if you wish to apply a 2 megarad dose to a sheet of polyethylene using 2 mev on a single exposures, you would find the results shown in Table VII. (It should be noted that the equipment can be operated at its rated capacity so long as the specimens travel the beam so the average dose rate is reduced.)

The dose rate considerations will play an important role in production source design. When circumstances dictate the use of a high penetration-low dose rate gamma sources the design should locate the material as close to the source as possible and surround the source with sufficient material to absorb as much of the available energy as is economically practical. This will demand a balance of source cost vs. product handling equipment. On the other hand, when a high dose rate electron accelerator is used, a scheme must be devised that will allow the equipment to operate at full power yet prevent excessive heating and damage to the product. This may be done by allowing the product to traverse the beam a number of times.

Although a process may seem economically practical from the standpoint of total dose, it may actually be impractical due to dose rate considerations. A process involving a part of complicated nature or thick cross-section will be plagued by large inventory and source requirements brought about by the inherent low dose rate of high penetration sources. The conflicting factors of thick cross-section parts and low penetration of high dose rate sources can also result in an impractical process.

Dose Variation

A major factor in the final design of an exposure system will be the allowable dose variation between irradiated parts and within each irradiated part.

In irradiations with accelerated electrons this problem is normally restricted to the latter, since the limited exposure area prevents any variation in the path traversed by the products through the beam. Although some improvement in the amount of cross-section variation can be achieved through the use of absorbers placed between the source and the product, this is at the expense of total penetration and would be applicable only in work with extremely sensitive films. Other than this there is little that can be done to overcome the basic restrictions of the electron beam sources.

In the case of gamma facilities, however, both variations arise. To overcome part to part variations, a system designed to give each part the same exposure history would be necessary. That is, all parts passing through the exposure area would follow the same route and have the same relative motion. The problem of variation within a part poses an even more difficult problem; this is especially true if the part is relatively large. This can be realized if you imagine a rod-shaped source which is extremely long compared to the part. Then, if surfaces of equal intensity are plotted at some fixed interval of intensity, we would have a series of concentric cylinders which, when cut prependicular to the source, would have the same appearance as waves

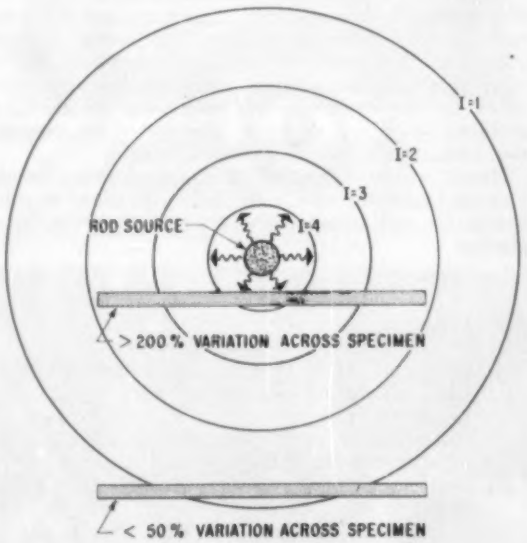

I=1
I=2
I=3
I=4
ROD SOURCE
> 200 % VARIATION ACROSS SPECIMEN
< 50 % VARIATION ACROSS SPECIMEN
I IS THE RELATIVE INTENSITY ON THE CYLINDRICAL SURFACES AT VARIOUS DISTANCES FROM THE RADIATION SOURCE.

Figure 1. Effect on specimen placement on dose variation.

about a pebble thrown into a pool. Such a cross-section about a radiation source is illustrated in Fig. 1. It can be seen that as a large part is moved closer to the source rod it will cut more of the surfaces of equal intensity and therefore will experience an increase in dose variation in a given period of time. To overcome this problem the source shape must be designed in such a manner that the result of the intensity pattern formed by the source and the motion of the part through this pattern will be a dose variation within the tolerances of the process.

Conclusions

It is difficult to draw any precise conclusions at this time about the overall role of atomic radiation in the field of plastics. The main difficulty stems from the fact that radiation does not perform any chemical reaction which cannot be done by conventional chemical methods. Thus, the problems reduce to:

1. Cost of radiation vs. cost of chemical catalysts.
2. Convenience, speed, feasibility and property advantages of using radiation vs. using chemical catalysts.
3. The largely unknown industrial technology of employing radiation vs. standard industrial technology of chemical catalysts.

The cost of radiation will continue to decrease for years, whereas the cost of chemical catalysts has leveled off and may even increase. Chemical accelerators will be found to make more efficient use of radiation, and lower its effective cost. Moreover, most plastics reactions are chain reactions and hence are uniquely favorable to radiation. For example, 100 electron volts of radiation energy may cause the combination of one molecule of benzene plus one molecule of water to form phenol at a cost of $20/lb of phenol. This same amount of radiation energy may cause the polymerization of 10,000 molecules of vinyl chloride monomer at a cost shown in Table I of 0.2¢/lb of polyvinyl chloride.

Regarding point 2, present industrial practice indicates that the cross-linking of polyethylene films and tapes already shows advantages over chemical cross-linking in speed, convenience and feasibility. On the technological side, we are convinced that concerted effort by the engineers will solve any technological problem, once the research laboratory demonstrates that radiation is the preferred tool.

Hence, we must conclude that atomic radiation will play an important role in the future in areas of polymerization, vulcanization and graft copolymerization of plastics.

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* * *

REINFORCING EPOXY WITH METAL FIBER

New compositions for tool and dies offer the possibility of unlimited variations in the field of metal-fiber reinforcing and holds out great potential to the reinforced plastics industry as well as the tooling industry.

A. P. Mazzucchelli

Development Laboratories
Bakelite Co.

Part II

This is the second and final part of a paper presented at the 36th Annual Meeting of the American Society of Tool Engineers. Part I appeared in the September issue of the SPE Journal. — editor.

COMMERCIAL CASE HISTORIES

In addition to information obtained from metal-fiber-reinforced compositions in test dies, data are available from more than sixty commercial dies constructed from these new materials. These dies were built co-operatively by the tool and die fabricating firms, Modern Pattern and Plastics, Inc., of Toledo, Ohio, and Warren Plastics and Engineering Company of Roseville, Michigan.

These companies also assisted in making the terminal-box test dies. The fabrication of these commercial dies was of significant value in pointing up and resolving practical problems as well as in building up case histories obtained under shop conditions. The most representative of the case histories are briefly described in Table V, with more detailed descriptions of several of the dies given below.

Radiator-Tank Top

One of the first commercial ES dies built, a punch for automotive-radiator-tank tops, about 23-in. x 4-in. x 7-in. deep, was run with a conventional iron alloy draw ring and pad and used to form 0.025-in. brass. A total of 11,000 stampings was fabricated by Long Manufacturing Division of Borg-Warner Corporation. As a result of this promising performance, a complete ES radiator draw die was built. (Figure 11 A-B). The complete ES punch and die was built with a steel trim line flange and a metal ring insert on top to form the filler neck. The die was cast in a steel box which formed the steel draw radius and surface. A metal draw ring was used. Thus the ES cast was limited to the more costly contoured areas, while the critical wear surfaces were of metal.

This die is still in operation, without any maintenance, and has run over 130,000 parts which have passed all inspection requirements. This represents one of the largest production runs ever achieved by a plastic die of this type.

Length and width have remained unchanged as has the 1.9-in. punch radius. After 50,000 stampings, the reinforcing rib radii increased from 0.45 in. to 0.060 in. at the top of the punch and from 0.19 in. to 0.50 in. at the curved lower ends. These curved ends represented 5 per cent of the bead area and were in highly stressed locations on vertical side walls. However, these changes in no way affected the performance of the stamping, and continued production is planned. There has been no loosening of the metal insert in the punch.

This die cost $2,225, compared with $3,000 to $5,500 for an equivalent steel die, as estimated by independent die shops.

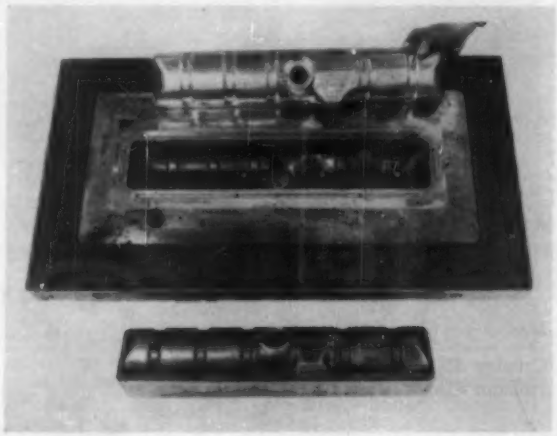

Fig. 11A & B — ES punch and die used to produce over 130,000 automotive radiator-tank-top stampings of 0.025-in. brass by Long Mfg. Div. of Borg-Warner Corp.

TABLE V

Performance of Commercial Fiber-Reinforced Epoxy Compositions

Name of Part	Composition Cast	Fabricator*	Approx. Part Size & Draw inch	Type Part	Performance Record
Radiator-Top Tank	ES Punch Iron die & ring	M	4 x 23 x 3	0.025″ brass	Completed run of 11,000 stampings. Flange (0.06″) at trim line requiring repair after 4000.
Radiator-Top Tank	ES Punch & Pad. Iron ring	M	4 x 23 x 3	0.025″ brass	Still running after 130,000 stampings. Used steel trim flange and ring. No maintenance.
Refrigerator-Bottom Panel 1st & 2nd draw	ES Contoured Punch & Pad Steel rings	M	16 x 21 x 1¼	0.036″ C.R.S.	Still running after 65,000 panels. No maintenance. One 0.08″ draw radius increased to 0.19″ after 5000 panels, remaining unchanged as 0.44″ after 15,000 panels.
Charcoal-Broiler Tray	ES Punch EG-SF Die & ring	W	21 x 27 x 1	0.029″ C.R.S.	Ran 1000 panels. Draw radius increased from 0.031″ to 0.11″. Now running with metal plate draw radius insert.
Cover-Draw Die	ES Punch EG-SF Die & ring	W	21 x 22 x 5½	0.050″ C.R.S.	Completed run of 1000 stampings. Draw radius increased from 0.125″ to 0.25″ after 300 and to 0.50″ after 700 additional stampings.
Aircraft Housing	ES Punch & upper ring. Ampco-bronze inserted polyester/glass lower ring	W	28 x 15 x 3½	0.040″ alum.	Still running after 500 stampings. Indicated no need for bronze inserts if ES lower ring used. Aluminum was not scratched.
Aircraft Reinforcing Section	ES-SF Punch & Pad	W	4 x 10 x ½	0.045″ stainless steel	Completed 200 parts. Draw radius 0.37″ remained unchanged; 0.06″ radius ends increased to 0.18″ and required metal inserting.
Aircraft Part	ES Punch EG-SF Die Steel rings	W	25 x 16	0.065″ stainless steel	Still running after 200 parts. No difficulty.
Stringer Z Section Radial Forming Die	ES on aluminum core	M	40 x 2½	0.32″ stainless steel	Still running after 80 parts. No difficulty.
Crosley Refrigerator Bottom Plate	ES Punch, Die & Ring. Metal beads	W	36 x 29 x 3	0.038″ C.R.S.	Tryout approved. Crosley refrigerator line and production abandoned.
Plastics Sign Vacuum Forming Die	ES	M	22 x 24	cellulose acetobutyrate methylmethacrylate	Still running after 2000 parts. No difficulty.
Vending Machine Panel Heated Matched Mold	EA	M	64 x 32	0.060″ polyester glass fiber mat	Made 728 panels. Scum buildup required cleaning every 20-80 panels. Steel pinch trim inserts in male mold had to be reinforced. Surface gloss wore. Heat up rate satisfactory and cure speed at 200°F. about same as with metal die.
Green Sand Rocker Arm Foundry Pattern	EA and Al. core cope and drag	M			Attained desired improved thermal conductivity and fewer rejects, due to sand drag, than R-T. Epoxy. Still operating after 100,000 castings.

*M = Modern Pattern and Plastics, Inc., Toledo, Ohio
W = Warren Plastics and Engineering Co., Roseville, Michigan

Aircraft Housing

In another case, a die, 28-in. x 15-in. x 11½-in. with a 3½-in. depth of draw, was constructed for the production of an aircraft housing from 0.040-in. aluminum for Fargo Manufacturing Company. A first die was built of a standard polyester-glass pressure-cast composition. After tryout it was necessary to add bronze to the rings to prevent wrinkles.

A second die was made with a punch and upper ring of composition ES, retaining the polyester-glass, bronze-inserted lower ring. This die has made about 500 panels to date and is still in operation. Performance has been found superior to polyester-glass, pressure-cast materials for the draw ring, making use of the bronze inserts unnecessary. Of particular significance was that fact that this ES die was capable of drawing aluminum without scratching.

Stringer Z Section

Built for Cyril Bath Company, a radial-forming die of this new-epoxy material was used for forming 80 parts of a Stringer Z Section of 0.032-in., type 17-7 PH stainless steel. (Figure 12) In this forming operation the brake-formed cross section, 2½-in. x 40-in., is stretched beyond its yield point and the die rotated into the straight part with a force-at-point contact of about 3000 pounds.

In the fabrication of this ES die, a ⅜-in. to ½-in. shell of steel-fiber-reinforced, heat-resistant epoxy was pressure cast against an aluminum core, using a steel-fiber mat carefully layed over the core. The cured cast was fastened securely to the aluminum core with screws. This die, illustrating a surface-pressure-casting technique, is still in operation and is performing satisfactorily, although volume requirements for the part are low. It is believed that these compositions will be particularly advantageous for such stretch dies when sharp corners must be formed.

Refrigerator-Bottom Panel

A refrigerator-bottom-panel draw die (Figure 13) for the Refrigeration Department of Hotpoint Company involved four ES punch and pad inserts for first draw and redraw dies, each with flat metal rings, to form a 0.036-in. cold-rolled-steel panel.

No particular difficulty was encountered in casting these inserts at 300 psi using a reinforced plaster mold.

These dies have made 65,000 acceptable panels and are still in operation. There have been no repairs required, and the contoured ES punch inserts have remained relatively unchanged. During the production run, the greatest change occurred due to wear in a sharp radius of the plastics insert of the redraw die, which was really an extension of the metal radius. This radius started at 0.08 in., increased to 0.19 in. after 5000 panels, and to 0.44 in. after 15,000 panels, remaining unchanged thereafter, which still met the requirements for this panel.

Delivery of these dies was made in five weeks whereas the equivalent all-metal dies would have required 10 weeks. At the same time, cost was $275 less for each of the dies.

These results indicate the applicability of metal-fiber-reinforced epoxy materials for contoured punch and pad inserts for low- and medium-production, metal-forming dies, in areas which will not wear seriously, using metal for the rings. Tentative results indicate that a ½-in. draw radius with 0.036-in. cold-rolled steel will not wear. There are many inside panels where such generous radii would be accepted functionally as part of the original design.

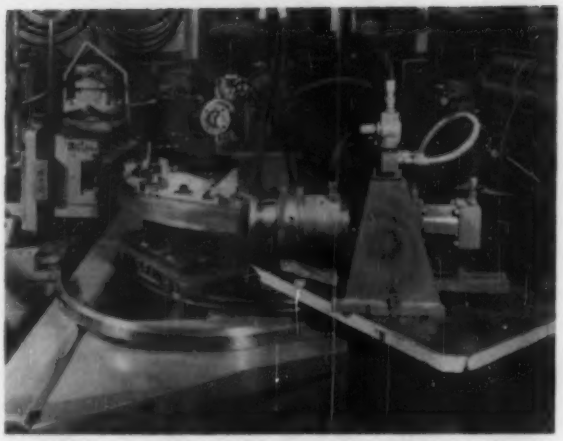

Figure 12. Radial forming die for 0.032-in. stainless-steel stringer Z section built for Cyril Bath Company. Die consists of an ES shell pressure cast on aluminum core.

Figure 13. Redraw die with ES punch and pad insert used for stamping over 65,000 refrigerator-bottom panels of 0.036-in. C.R.S.

Prototype Defense Parts

Thirty-five EG-SF dies have been successfully used on a classified government project. This program has demonstrated that such dies can be satisfactorily used for drawing 3/16-in., stainless-steel prototype panels over a 2-in. radius to a depth of about 18 inches. Boiler-plate draw-radius inserts were used in some of the most critical dies. Otherwise, the dies were complete EG-SF mass castings, weighing in some cases as much as 7,500 pounds.

Matched Mold and Foundry Pattern

Besides the above commercial ES and EG-SF metal-forming dies, a large EA matched mold and an EA

Figure 14. Heated matched mold fabricated of composition EA. Used to mold vending machine panel of polyester glass mat, these molds measured 75 in. x 42 in. and each weighed 600 pounds.

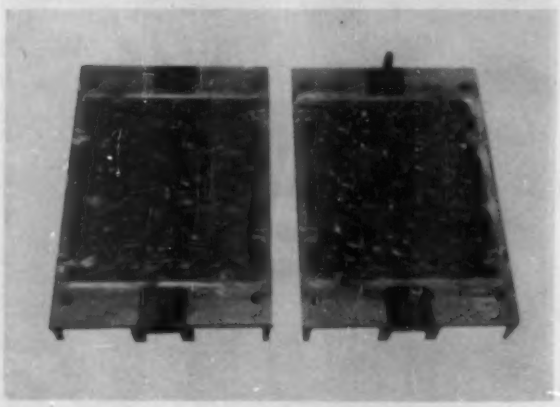

Figure 15. Green-sand foundry pattern of composition EA which revolved an operating-temperature problem because of superior thermal conductivity. The pattern has produced over 100,000 sand molds to date.

TABLE VI

Typical Costs of Fiber-Reinforced-Epoxy Dies Versus Metal Dies*

Name of Die	Iron	Fiber-Reinforced Epoxy
Test Terminal Box	$2,500-4,000 1,218-1,330 (Zinc base alloy)	$ 982 (ES)
Refrigerator Bottom Panel		
1st draw	4,100	3,825 (ES)
2nd draw	3,015	2,740 (ES)
Radiator Tank Top	300-5,500	2,225 (ES)
Charcoal Broiler Tray	3,175-5,350	2,380 (EG-SF)
Vending Machine Panel (Matched Mold)	9,000-12,000 (Aluminum) 15,000-25,000	5,950 (EA)
Foundry Pattern	3,000	1,000 (EA)

*As estimated by independent die shops.

green-sand foundry pattern, listed in Table V, have been placed in production.

A large matched mold was built in four weeks for General American Transportation Corporation (Figure 14) and made 728 vending-machine panels of polyester resin and glass fiber mat, 64 x 32 in. in size by 0.60-in. thick. Heat-up rate using steam platens was satisfactory, and cure speed attained was in the range of an equivalent metal die. Major difficulties were loss of surface lustre and the requirement of periodically cleaning a deposit which formed on the mold, although this was minimized by use of a baked silicone coating. Nevertheless, these results are considered promising, particularly in view of the inherent advantages of EA in high thermal conductivity, high heat distortion, toughness and good machinability, all of which still make this a desirable material for further development and evaluation.

An EA green-sand foundry pattern (Figure 15) for rocker-arm castings was fabricated for operation with recirculating hot sand. Although standard epoxies have proved satisfactory for cold-sand foundry patterns, the recirculating hot sand had in the past resulted in a high rejection rate of castings due to sand drag. To avoid condensation on the pattern and sand-drag difficulties, it was desired to operate the pattern above the sand temperature. For this reason the highest thermal conductivity was needed to absorb heat from the hot air used to heat the patterns. In this way, the highest pattern surface temperatures could be obtained with the available hot-air temperature. This EA pattern, because of its far superior thermal conductivity, resolved the operating-temperature problem and has produced over 100,000 satisfactory sand molds to date.

The over-all cost of these fiber-reinforced epoxy compositions will vary, depending on the volume and specific combination used, but it will generally be in the range of present epoxy tooling materials. At the present time, dies made from these compositions and using the pressure casting technique will cost more than a simple casting of compounded epoxy. For this reason, these materials are only intended for use where their particular properties are needed and their known advantages extend application to areas where conventional plastic tooling materials are marginal or unsatisfactory. Nevertheless, as shown in Table 6, there are still considerable savings over the cost of equivalent all-metal dies.

Furthermore, because of savings in machining and spotting, such die-cost comparisons often do not entirely reflect the cost and time advantages which normally accrue through the use of plastics dies instead of metal dies. These savings are well known and are also generally applicable to these metal-fiber-reinforced epoxy tooling compounds. For example, in the refrigerator-panel case history described above, the actual dollar saving with the plastics dies was not much greater than if all-metal dies were used. However, production was able to begin 5 weeks earlier.

To date, the performance records of commercial dies fabricated from these compositions confirm the results obtained with test dies. To summarize, they both indicate the following preliminary practical utility range for ES and EG-SF compositions. It should be noted that these commercial tools were built early in this program, during which time tooling techniques for reinforced dies with a metal-fiber-flocked surface were being evolved and still improved.

1. *Prototype or Development Draw Dies*—For deep draws of heavy metals, and large compound-contour stampings of up to ¼-in. thick stainless steel.

Prototype panels of 3/16 in. stainless steel have been drawn over a 2-in. radius to a depth of 18 in. without radius breakdown. Using 0.050-in. C.R.S., draw radius will increase from ⅛-in. to ¼-in. for a 5½-in. depth of draw after 300 stampings and to ½-in. after an additional 700 stampings.

2. *Low-Production Draw Dies*—For runs of 1,000 to 10,000 stampings, without metal rings or inserts. Gage of metal and design of stamping will have to be considered.

For example, 1,000 stampings of 0.038-in. C.R.S. can be made with a depth of draw up to 2½-in., if draw radius increase from ⅛-in. to ¼-in. is acceptable. In drawing the same number of stampings from 0.029-in. C.R.S. over a 1/32-in. radius to a depth of 1 in., the radius will remain sharper than ⅛ inch. For stampings above this range one blank-holder surface should be of metal. Using 0.036 C.R.S. for a 1¼-in. deep panel, 5,000 stampings are possible with a draw-radius increase from an initial 5/64 in. to 12/64 in., while 10,000 panels can be drawn to a depth of ⅝ in. with a radius increase from 7/64 in. to 9/64 inch.

3. *Medium-Production Draw Dies*—For runs of 10,000 to 50,000 stampings, in which contoured punches and pads are used with metal inserts, draw rings, and blank holders. Compositions ES and EG-SF can be used for areas which are not subject to considerable wear, for inside panels where radii of ½ in. are acceptable, or where wear to such radii can be tolerated.

In one such die, 65,000 panels of 0.036-in. C.R.S. have been produced satisfactorily.

4. *Medium-High-Production Draw Dies*—For runs of 50,000 to 150,000 or more stampings of the thinner and more easily formed metals, such as 0.025-in. brass.

Thus, 50,000 stampings or more of such metals can be produced if bead radii are 1/16 in. or more, if very highly stressed radii are ½ in. or more, and if metal inserts are used on sharper radii wearing parts. Such dies will hold a screw-fastened insert satisfactorily and with less mark-off than with standard epoxies.

5. *Flanging, Trimming, Restrike, and Secondary Operation Dies*—Highly desirable because of superior machinability and toughness, plus ability to retain and support dowels, screws, and steel cutting edges.

6. *Hydroform and Rubber Pad Forming Dies*—Mass castability, abrasion resistance, and lack of scratching of soft aluminum and stainless steel provide advantages over current materials.

7. *Stretch Dies*—For more difficult sharper radii, and for hot stretch forming dies, where present materials are marginal.

8. *Fixtures and Gages*—For special applications requiring mass casts for needed rigidity, or where heat resistance and abrasion resistance make it more suitable than materials in current large-scale use.

Potential uses for composition EA, which take advantage of its capacity for mass castability, high heat resistance, and high thermal conductivity, include: precision metal casting molds, heated matched molds (for low pressure use), foam and expandable plastics molds, vacuum forming molds, slush molding dies, and foundry patterns.

Although limited studies of this composition have indicated satisfactory service in such applications, it is felt that experience and use within the industry will greatly increase this suitability.

Conclusion

Both laboratory results and commercial experience have been sufficiently successful to warrant the presentation of these new compositions to the tool and die industry in their present form. However, they are really examples of a basic technique, namely, the reinforcing of thermosetting resin castings with metal fibers.

For example, by using the principles involved in these compositions, metal-fiber mats may eventually be employed like glass cloth for lay-ups. In another direction, physical structures have been made experimentally by a simultaneous or alternate epoxy-resin-spraying, metal-fiber-flocking process. Similar results have been obtained by brushing the resin into the metal flocking, and allowing each layer to gel before adding another. Such structures can be densified by rolling down or impacting the composition prior to curing. These and other techniques offer the possibility of practically unlimited variations in the field of metal-fiber reinforcing and hold out great potentiality to the reinforced plastics industry as well as to the tooling industry.

For the present, however, the advances provided by these types of metal-fiber-reinforced epoxy compositions are already significant. Besides retaining the benefits of current plastics die materials, namely, low cost, light weight, and shorter tooling time, they have the following additional advantages:

1. Outstanding performance in metal forming dies.
2. Ability to be mass cast in large volumes to complicated shapes with low shrinkage and controlled exotherm, while obtaining higher impact strength, heat distortion, rigidity, and resistance to thermal shock.
3. Up to 60 times better thermal conductivity—equivalent to some grades of stainless steel, 35 per cent that of regular steel, and 8 per cent that of aluminum.
4. Can be made easily machinable, magnetic, and suitable for induction and low-voltage resistance heating.

A limiting factor to these advantages are higher process and equipment costs as compared with present plastics materials. Improved metal fibers and the development of mechanized fabrication techniques will simplify fabrication, lower costs and extend large-scale use. For the present, however, the use of these compositions will be confined to applications where present materials are inadequate. Other improvements to be desired include further increased die-surface hardness, wear, erosion resistance, and heat resistance. Research continues in all of these areas, with definite progress being made. In this regard, a new draw-die abrasion test has been developed which is being used, more expeditiously and economically than the terminal-box test die, for practical evaluation of new resins and specialty metal fibers for metal-forming die applications.

Materials of this type could never be developed without the co-operation of many segments of the tool and die industry. To the tool and die fabricators, end users, and others, who rendered such valuable assistance in the testing and evaluation of these compositions, Bakelite Company wishes to acknowledge its appreciation.* As this industrial co-operation continues, it is confidently expected that use and familiarity with these materials will extend performance records.

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* Specific appreciation is expressed by the author to Mr. T. E. Bugel of Bakelite Co., Development Dept., for his laboratory work, and to Mr. A. Juras, Plastics Tooling Consultant, for his help and guidance throughout this program.

PERFLUOROCARBON RESIN

A melt-extrudable material similar to polytetrafluoroethylene in electrical properties, chemical inertness, permeability and weatherability, but having superior thermal stability and good physical properties at elevated temperatures.

R. S. Mallouk and W. B. Thompson
E. I. duPont deNemours & Co., Inc.

A FLUOROCARBON copolymer, Teflon 100X perfluorocarbon resin, has been developed by the copolymerization of tetrafluoroethylene and hexafluoropropene. The new product softens at about 545°F and is readily extruded at temperatures of 650°F to 740°F. Its low melt viscosity, one millionth that of Teflon 1 tetrafluoroethylene resin, and high critical shear rate permit the melt extrusion of wire coating, rod and tubing, the blowing of bottles, and rapid heat sealing of films.

The unique combination of electrical properties, chemical inertness, low permeability and excellent weather resistance of perfluorocarbon, is attributable to its completely fluorinated structure. Finally, the copolymer exhibits thermal stability and retention of its physical properties at temperatures to 480°F.

Basic Physical Properties

The basic physical properties of the copolymer are recorded in Table I. They describe a tough resin of moderate strength and stiffness. In common with tetrafluoroethylene resin, perfluorocarbon resin exhibits the anti-sticking performance and low coefficient of friction characteristics of completely fluorinated polymers. Both resins are similar in specific gravity, ultimate tensile strength and elongation, yield strength, flexural modulus, hardness and brittleness temperature. The copolymer is tougher as judged by tensile impact strength, but the tetrafluoroethylene homopolymer exhibits a higher flex life. Commercial polytetrafluoroethylene resins exhibit a higher crystalline melting point and heat distortion temperature than the copolymer.

Properties at High Temperatures

The influence of test temperature on the physical properties of the copolymer is summarized in Table II. It is evident that the copolymer retains useful mechanical properties from —300°F to over 400°F.

The variation of tensile properties with temperature is compared with that of other fluorine-containing polymers in Fig. 1. The data for polytetrafluoroethylene (Teflon 6) and polychlorotrifluoroethylene (Kel-F 300) are taken from the review by Doban, Sperati and Sandt (Ref. 1). The behavior of the copolymer is very similar to that of the homopolymer, up to the temperature at which the copolymer softens and melts. Table I shows that the homopolymer melts about 65°F higher than the copolymer, which in turn melts about 100°F higher than commercial polychlorotrifluoroethylene resins.

Perflurocarbon has shown no evidence of degrading during 4,000 hours of exposure in a circulating air oven at 410°F. The melt viscosity of the polymer remained essentially unchanged throughout this 4,000-hour exposure.

Similarly, tensile properties and toughness are retained even after long exposure times at 400°F, indicating that crystallization has little effect on mechanical properties. Table III summarizes these data. Because these property changes in the copolymer are small, it is likely that the upper service temperature will not be limited by the temperature at which a quenched sample begins to anneal at an appreciable rate. It is also likely that the effect of cooling rate during fabrication upon the properties of the product will be small and of minor importance.

Electrical Properties

The electrical properties of the copolymer are indistinguishable from those of the tetrafluoroethylene homopolymer. This is to be expected from the completely fluorinated structure of both polymers.

The electrical properties of the copolymer are summarized in Table IV. The dissipation factor is less than 0.0003 and the dielectric constant less than 2.2 over the entire spectrum measured to date (i.e., 60 cycles to 60 megacycles).

Volume resistivity is greater than 10^{15} ohm-cm, even after prolonged

This paper was presented at the Fourteenth Annual Technical Conference of SPE.

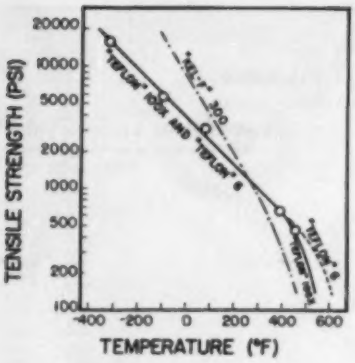

Figure 1. Tensile strength vs. temperature.

soaking in water. The surface resistivity is high and although it melts when exposed to an arc, it does not carbon track.

Short-time dielectric strengths are high. The range for 1 to 10 mil thicknesses is 2,000 to 4,000 volts/mil. Recommended working stresses are of course lower than this.

Chemical Resistance

The excellent chemical resistance of the copolymer at temperatures as high as 400°F is equal to that for the polytetrafluoroethylene resins. The resistance to chemical attack associated with the completely fluorinated structure is demonstrated by the record tabulated in Table V.

In these experiments, retention of tensile strength was used as a measure of the resistance of the copolymer to chemical attack. The copolymer exhibits no significant change in tensile strength after exposure to the organic and inorganic materials listed in Table V for eight hours at 400°F. Even after 120 hours at this temperature, the polymer resists the action of Skydrol* hydraulic fluid (phosphate ester), acetophenone, pyridine, 20% hydrochloric acid, and 30% sulfuric acid. The extreme chemical inertness of the perfluorinated polymers is in sharp contrast to the performance of incompletely fluorinated polymers.

Permeability

Permeability data are presented in Table VI. The permeability to most reagents is quite low, particularly in the cases of 98% sulfuric

*Registered Trade-mark of the Monsanto Chemical Company.

TABLE I

Basic Physical Properties
Typical Values Quenched Samples

	Teflon 100X Perfluorocarbon Resin	Teflon 1 Tetrafluoroethylene Resin	Teflon 6 Tetrafluoroethylene Resin
Tensile Strength, psi	3,000	2,800	3,000
Elongationn, %	370	270	360
Stress at yield	1,900	1,800	1,600
Flexural modulus, psi	82,000	60,000	78,000
Tensile impact strength, psi	800	300	400
Hardness, Durometer, D Scale	55	—	65
Heat distortion temperature			
at 66 psi, °F	162	—	248
at 264 psi, °F	129	—	—
Taber abrasion test,			
CS-17, 1000 g load mg/1000 cycles	13	—	—
Brittleness temperature, °F	−130	—	−148
Flex life			
MIT tester	4,500	—	—
Du Pont Teflon tester	3,000	60,000	$>10^6$
Coefficient of friction against steel	0.09	0.025	0.025
Melting point, °F	545	620	620
Specific gravity	2.1–2.2	2.1–2.2	2.1–2.2
Water absorption	0.0	0.0	0.0
Burning rate	nil	nil	nil

TABLE II

Effect of Temperature on Physical Properties of Perfluorocarbon Resin
(Typical Values)

Temperature	Yield Stress	Tensile Strength	Elongation	Tensile Modulus	Flexural Modulus
°F	psi	psi	%	psi	psi
−321	16,000	16,000	5	487,000	—
−108	5,750	5,750	40	118,000	—
73	1,930	3,080	309	—	85,000
212	—	—	—	—	17,000
392	450	650	225	—	7,000
455	—	450	180	—	—

TABLE III

Properties of Heat-Aged Perfluorocarbon Resin
Circulating Air Oven, 400°F

Preparation of Sample	Exposure Time at 400°F	Tensile Strength	Elongation	Specific Gravity	Melt Viscosity 720°F
	hrs		%		poises
Compression molded	0	3,370	322	2.152	7.6×10^4
Water quenched	568	2,990	333	2.166	7.9×10^4
Compression molded	0	3,050	331	2.163	7.6×10^4
Air quenched	1,000	2,600	301	2.172	7.8×10^4
Compression molded	0	2,900	336	2.171	7.6×10^4
Slow cooled	1,000	2,430	291	2.174	7.9×10^4

acid, 20% hydrochloric acid and 50% sodium hydroxide solution.

Weather Resistance

The unusual weather resistance of the tetrafluoroethylene resin, which is attributable to its completely fluorinated structure, is also evident in the copolymer. The electromagnetic absorption spectrum of the copolymer differs only from that for polytetrafluoroethylene by an absorption band at 10.2 microns. The absence of bands from 0.3 to 2 microns, the region of maximum solar radiation, is indicative of a high resistance to photodegradation. The lack of photosensitive groups reduces the susceptability of the copolymer to the effects of sunlight. Freedom from photodegradation is substantiated by accelerated weathering experiments. No measurable changes in the physical properties have occurred after 5,000 hours in an XW Weather-Ometer.

In addition, high intensity, ultraviolet radiation is ineffective in providing structural changes even after 6,100 hours at 130-140°F in an atmosphere with a relative humidity of 50%. The copolymer also resists the combined action of ultraviolet light and 100 ppm of ozone for at least 1,000 hours. These results suggest at least a 5-20 year period of outdoor weathering without any changes in the physical properties of the copolymer. Thus, copolymer film appears suitable for such long-term outdoor uses as solar stills or greenhouse covers. In fact, several experimental solar stills designed around and utilizing film of this copolymer are now being tested at various spots in the United States.

General Principle of Processability

At 720°F, molten perfluorocarbon has a viscosity of about 70,000 poises. In addition, the polymer has a high capacity for being drawn in the molten state and over 100:1 reduction in cross section is possible without leaving residual strains. Thus, with wire coating, where it is possible to extrude thick sections at relatively low linear rates and then draw the melt to obtain thinner sections at high rates, production rates as high as 600 ft/min. have been achieved. On the other hand, rates are considerably slower when such draw-down is not possbile. For instance, a free extrusion of ½" by ⅝" tubing would begin to show surface roughness at about 2½ feet/min. This surface roughness is caused by the phenomenon of melt fracture which has been discussed recently by Tordella (Ref. 2). The maximum rate of flow of molten polymers through dies is limited for practical purposes by surface roughness occurring above a certain critical shear rate. For perfluorocarbon at 720°F this actual rate is about 60 sec^{-1}. Thus, the rate at which it can be converted into extruded shapes depends not only on die geometry but also on the poduct involved and the possibility of utilizing melt draw. Fig. 2 shows a variety of shapes and products fabricated from perfluorocarbon.

TABLE IV

Electrial Properties of Fabricated Perfluorocarbon Resin

Property	Test Method	Average Value
Dielectric Strength, 15 mil film		1000 volts/mil
Dielectric Constant 73°F	D-150-54T	
Frequency: 100 cps		2.2
1,000 cps		2.2
10,000 cps		2.2
60,000,000 cps		
Dielectric Constant, 1000 cps	"	
Temperature: −40°F (−40°C)		2.2
32°F (0°C)		2.2
212°F (100°C)		2.2
392°F (200°C)		2.2
464°F (240°C)		2.2
Dissipation Factor, at 73°F	"	0.0002
Frequency: 100 cps		0.0002
1,000 cps		0.0002
10,000 cps		
60,000,000 cps		
Dissipation Factor, at 1000 cps	"	0.0002
Temperature: −40°F (−40°C)		0.0002
32°F (0°C)		0.0002
212°F (100°C)		0.0002
392°F (200°C)		0.0002
464°F (240°C)		
Surface Arc Resistance	D-495-42	165 sec[a]
Volume Resistivity	D-257-52T	2 x 10^{15}
Surface Resistivity	D-257-52T	2 x 10^{13}

[a] Samples melted in arc after 15 seconds, but did not carbon track.

TABLE V

Chemical Properties of Fabricated Perfluorocarbon Resin

Resistance to Chemical and Solvent Attack

One Week Exposure at 212°F	Tensile Strength, Elongation
Skydrol, Hydraulic Fluid	Unchanged
Benzene	Unchanged
Carbon Tetrachloride	Unchanged
Ethanol	Unchanged
Acetophenone	Unchanged
Piperidine	Unchanged
20% Hydrochloric Acid	Unchanged
30% Sulfuric Acid	Unchanged
50% Sodium Hydroxide	Unchanged
Red Fuming Nitric	Unchanged

120 Hour Exposure at 400°F	Tensile Strength Elongation
Skydrol Hydraulic Fluid	Unchanged
Acetophenone	Unchanged
Piperidine	Unchanged
20% Hydrochloric Acid	Unchanged
30% Sulfuric Acid	Unchanged

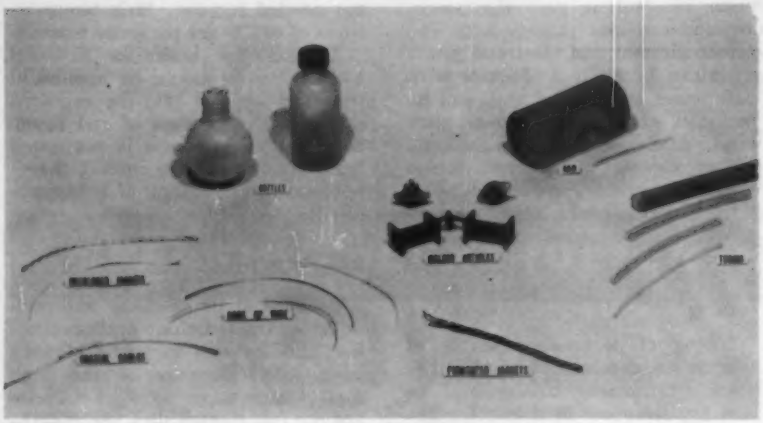

Figure 2. General products fabricated from Teflon 100X perfluorocarbon resin.

TABLE VI

Permeability of Perfluorocarbon Resin

A—Permeability to Liquids, 77°F	
Water	0.02g/100 in^2/day-mil
Ethanol	0.05g/100 in^2/day-mil
Benzene	0.15g/100 in^2/day-mil
Carbon Tetrachloride	0.11g/100 in^2/day-mil
Piperidine	0.04g/100 in^2/day-mil
Acetophenone	0.50g/100 in^2/day-mil
B—Permeability to Acids and Bases	
Red Fuming Nitric Acid	7.5g/100 in^2/24 hr-mil
Sulfuric Acid — 98%	1×10^{-5} g/100 in^2/24 hr-mil
Hydrochloric Acid — 20%	0.01 g/100 in^2/24 hr-mil
Sodium Hydroxide — 50%	0.01 g/100 in^2/24 hr-mil
C—Permeability to Gases	
Carbon Dioxide	1860 cc/100 in^2/24 hr-mil
Oxygen	160 cc/100 in^2/24 hr-mil
D—Moisture Vapor Transmission Rate (Cellophane Method)	
	33 g/100 m^2/24 hr-mil

TABLE VII

E-22 Wire Coated with Perfluorocarbon Resin

Test Performance in Military Specification MIL-W-16878-A/5

Test	Specification	Measured Value
Spark Test	3 kv (minimum)	No break at 4 kv
Dielectric Strength	250 v/mil (minimum)	1000 v/mil
Insulation Resistance	10^9 ohm/1000 ft (minimum)	10^{10} ohm/1000 ft
Heat Resistance, 96 hr at 480°F		
a. Mandrel Wrap	2.5 kv test	No break at 4 kv
b. Shrinkage	1/8" (max)	1/32 in avg
Cold Bend Mandrel Wrap	2.5 kv test	No break at 4 kv
Soldering Shrinkage	1/8" (max)	<1/32"
Dielectric Constant	2.5 (max)	2.05
Dissipation Factor	0.005 (max)	0.0003
Flammability		OK
Surface Leakage		OK

Extrusion Equipment

Conventional extrusion machines can be used in the processing of the copolymer. Extruders with barrels having a length-to-diameter ratio greater than 15:1 are preferable and a corrosion-resistant barrel liner is recommended.

In general, screws should have a constant pitch with a sudden compression in the ratio 3:1. Like the barrel, the screws should be of corrosion-resistant metal, such as Z-nickel.

The extruder should be heated electrically. A conventional 2" extruder having 9,000 watts capacity on the barrel has proven wholly adequate. Typical temperature settings on the extruder barrel are:

Rear of barrel	- 500°F
Center of barrel	- 620°F
Front of barrel	- 735°F
Adaptor and die	- 740°F

Because, at processing temperatures, the copolymer releases small quantities of toxic vapors in substantially the same way as other Teflon resins, good ventilation of the processing equipment must be provided. A hooded exhaust duct should be placed over the extruder hopper, die, and any other area where Teflon 100X at 400°F or hotter is exposed during processing.

Wire Insulation

In extruding wire insulation, high production rates are achieved by extruding a tube having a larger internal diameter than the wire, and then drawing the large tube down to wire size. A suitable crosshead type die design is shown in Fig. 3. Vacuum may be applied to the inside of the extruded tube through the wire guide to draw the tubing down onto the wire. It is possible to apply good coatings without the use of a vacuum system, but the range of coating thickness attainable from any one die set is narrower if a vacuum is not used. Furthermore, to get tight coatings the air gap between the die and water quench must be more carefully regulated and should, in general, lie in the range 2" to 6".

For a 6 mil insulation thickness on 22 gauge stranded wire, a die opening to extrude a tube 0.500" in outside diameter with a bore 0.300" in diameter formed by the wire guide works very well. By varying the wire speed this same tooling can be made to give good coatings over the thickness range 5 to 15 mils.

Data in Table VII represent typical results on Type E-22 wire coated

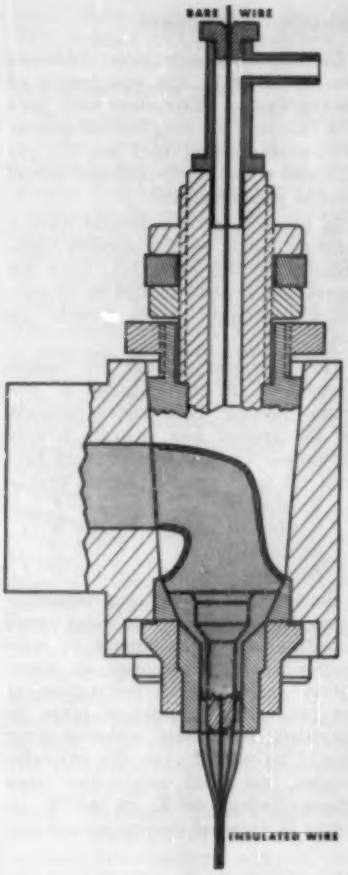

Figure 3. Crosshead and die for wire coating.

with perfluorocarbon resin and subjected to tests in military specification MIL-W-16878-A/5. It is evident that the insulation meets the specifications set.

One main interest in heavy coatings over ¼" thick is for use in coaxial cable cores. Draw-down techniques have not yet been successful in producing this type of product. It appears feasible, however, to produce these very heavy coatings by a "forming box" technique. In this process the melt passes from the die into a confined channel having the same cross section as the die proper, but having cooled walls to solidify the extrudate while maintaining its shape. Since draw down is not used to increase linear rate, the extrusion rate for coaxial cable core may be quite low, i.e., a few feet per minute.

Another wire coating application of great interest is in the field of jacketing. Using the same technique of "tubing on" the stock, abrasion-resistant jackets with excellent thermal and electrical properties can be applied. Jackets with thicknesses as low as 3 mils can be extruded at high rates over wire braid, shield single or multi-conductor cables, or coaxial cables where the primary insulation is of a tetrafluoroethylene resin or perfluorocarbon resin, or other resins such as silicones.

Tubing

Tubing of perfluorocarbon is of interest as slip-on electrical insulation, instrument tubing and in hose applications. In diameters below about ½" and wall thicknesses below 60 mils, tubing can be produced by a free extrusion technique involving draw down of the melt as it emerges from a die annulus. As the size desired increases, the process becomes progressively more sensitive largely from the point of view of shape retention and take-off techniques.

Larger diameter, thicker walled tubing may be produced by conventional "forming box" techniques wherein the molten resin is passed through a relatively long die land and then immediately into a water jacketed cooling chamber where it is pushed against the chilled walls (125°F) by light air pressure. The "forming box" should be insulated from the die by a good heat resistance gasket to keep the die lands from chilling and thus causing sheared rough surfaces on the extrudate.

Rod Stock

Rod stock may be extruded from perfluorocarbon resin if means of cooling are provided to control the shape and help avoid bubble formation or shrinkage voids. Cooling can be accomplished by attaching a water jacketed extension much like a "forming box" on the face of the die. In making rod stock, the cooling chamber is relatively long, and even so, cooling capacity may be the rate limiting factor in the process. For 2" rod, the cooling chamber should be 5' to 6' long. Production rates of 10 to 15 lb/hr may be achieved. Higher linear rates may be attained for small rod stock because of the thinner section, but a cooling jacket of nearly the same length should be used.

It is advantageous in making rod to use extrusion temperatures somewhat lower than normal because of the cooling problem and the fact that the lowest possible viscosity is not needed for rod. Melt temperatures of 650°F are perfectly feasible.

An external brake or artificial back pressure should be applied at the start-up and may be required during the extrusion of rod stock. In this way the melt is prevented from puddling in the cooling chamber and the formation of bubbles is eliminated.

Blown Bottles

Because of its viscosity and melt draw characteristics, perfluorocarbon handles well in bottle blowing operations. Because of the high melt temperature used, the cycles are not fast though they are reasonable. The mold is run hot, preferably at 300°F to 400°F.

Rework

Perfluorocarbon resin can be reworked several times without greatly sacrificing the properties attainable with virgin material. Extreme cleanliness is desirable because contamination may change the processing characteristics, or impair the electrical properties of the resin. If the resin has developed a gray color, it may be whitened to some extent by drying in an air oven at temperatures up to about 500°F for 24 hours or more depending on the amount of grayness.

Conclusions

Teflon 100X is a true perfluorocarbon polymer with a melt viscosity low enough to permit extrusion by techniques commonly used with thermoplastic polymers. Products produced from perfluorocarbon have an outstanding combination of properties: excellent dielectric characteristics over a wide range of temperatures and frequencies, heat resistance capable of continuous service at 400°F and higher, toughness from —600°F to 400°F, chemical inertness, essentially no moisture absorption, and outstanding weather resistance. Accordingly, it is felt that perfluorocarbon will find broad application in such important and basic industries as aircraft, missile, electronic and electrical, chemical and petroleum, and many others.

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Edited by R. D. Sackett
Technical Service Associate
Monsanto Chemical Company

SPEAKING of EXTRUSION

NYLON 6 TUBING

Extrusion Techniques and Effect of Environment and Processing Conditions on its Strength

J. L. O'Toole, H. G. Tinger and T. R. von Toerne
Applications Research Laboratory
Plastics and Coal Chemicals Div.
Allied Chemical Corporation

THE VOLUME and diversity of the uses of nylon 6 (polycaprolactam) tubing are steadily increasing in industry as a result of the outstanding properties—light weight, high strength, extreme toughness, retention of properties at elevated temperatures, and ease of extrusion—combined in this material. Among the more promising applications being developed are instrumentation air lines, automotive lubrication systems, hydraulic lines, air supply lines, water tubing and flexible shaft housings. The great interest being shown by designers and consumers in this material leads us to forecast a rapid growth in its use. Therefore, it is most important that both the advantages and limitations of nylon 6 tubing be thoroughly explored, especially those peculiar to polyamides.

Nylon 6, like all engineering materials, is affected by environmental and processing conditions. We will discuss the effects of some of the more important of these conditions to facilitate intelligent processing and use of this versatile material. In addition, the technique of its extrusion will be described.

Extrusion of Nylon 6 Tubing

The details of the extrusion equipment and techniques used are described in the following paragraphs.

This is a condensation of a paper presented at the Fourteenth Annual Technical Conference of SPE.

Extruder

Cylinder: 2½-in. diameter.
Heating: Electrical—4 zones on barrel, 1 zone on head, 1 zone on die.
Screw: Single flighted, constant pitch—2½ in., 3.5 compression ratio, 20:1 L/D, 4 flights in metering section.
Drive: 15-hp, variable speed, d-c.
Average output: 18-30 lb/hr.

The head, adapter, spider, die and mandrel (Fig. 1) are streamlined as much as possible to provide a smooth flow of the nylon melt. A pressure gage and stock thermocouple are used in the extruder head to assist the control of processing conditions.

Post-forming, Guiding and Cooling

Relatively simple post-forming and cooling equipment is required for the horizontal extrusion of small diameter nylon tubing. Fig. 2 shows the general arrangement of the cooling tank and post-forming facilities used in this study. The tank and overflow trough on which it rests are constructed of stainless steel. The forward 6 inches of the tank are stepped down to provide a water overflow and level control. Further control of the water level is accomplished by the use of a rotameter which aids in maintaining a constant flow of water into the tank.

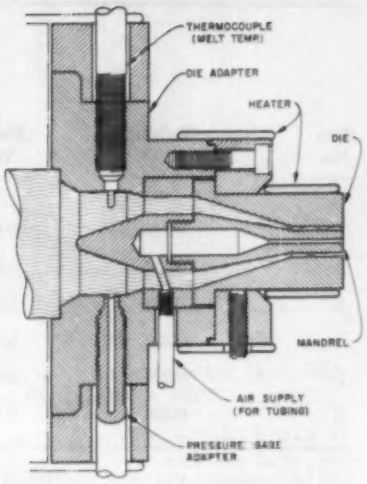

Figure 1. Die and mandrel arrangement for extruding Plaskon nylon tubing.

Bolts located on the sides of the trough permit lateral adjustment of the tank while the stands that support the trough are equipped with threaded posts to permit vertical and longitudinal adjustment. The temperature of the cooling water is varied by a thermostatically-controlled recirculating heater installed in the water supply line to the tank.

The post-forming tools consist of a series of upper and lower contoured plates, submerged in the water, which guide and round the tubing as it passes through the tank. The extruded tubing enters the tank through a circular orifice with a diameter equal to 1.5 times the finished tubing diameter. As the tubing passes through the post-forming tools, it is solidified by the cooling water. Compared to most thermoplastics, nylon 6 has a narrow melting point range (approximately 18°F) but a wider range than type 66 nylon. However, once it solidifies it is relatively difficult to form. Therefore, it is necessary to guide and form the extrudate properly

Figure 2. Close-up of forming plates showing the extruded tubing as it emerges from the die and passes through the water bath.

TABLE I

Experimental Extrusion Runs

Run No.	Tubing OD	Tubing Wall	Plaskon Nylon	Screw Speed	Take-off	Output	Bath Temp.
	in.	in.		rpm	fpm	lb/hr	°F
1	0.125	0.025	8201[1]	10	70	17	95
2	0.125	0.025	8201	10	70	17	130
3	0.250	0.020	8205[2]	17	50	22	84
4	0.250	0.020	8205	17	50	22	180
5	0.250	0.030	8205	22	50	30	84
6	0.250	0.030	8205	22	50	30	180

[1]A medium viscosity extrusion grade nylon.
[2]An Ultra-high viscosity extrusion grade nylon.

during the initial cooling stage. This can be done simply as shown.

Internal Air Supply

Adjustment of the low pressure internal air supply and the take-away speed permits the extrusion of a variety of tubing sizes with one die bushing and one mandrel. The air supply system consists of two pressure regulators in series with a surge tank. A water manometer is inserted in the line to indicate pressure. This type of system makes it possible to control the internal air pressure within 0.25 cm of water.

Experimental Procedure

The data are based on six extrusion runs described below. Over 100 runs were made during this study; for simplification, only a representative six will be discussed. The[illegible] runs are explained in Ta[illegible]

The [illegible]-in. OD tubing was extruded with a 0.250-in. diameter die bushing and a 0.125-in. diameter mandrel. The ¼-in. OD tubings were extruded with a 0.372-in diameter die bushing and a 0.250-in diameter mandrel. The quench-water flow rate, the air gap between the die and the quench bath, and the stock temperature were kept constant. The stock temperature was 470°F.

Analysis of Properties

The mechanical properties of nylon 6, like all polyamides, are significantly affected by the environment to which it is exposed and the conditions under which it is processed. This investigation covers the effect of absorbed moisture and two processing conditions, water-bath temperature and post-extrusion annealing, on the strength of the extruded tubing. Other environmental factors such as ambient temperature, ultraviolet light, and certain chemicals, also have an effect on nylon and should be considered wherever they are used. However, for many applications, the effects of these environments are not as important as the effect of moisture content.

Effects of Moisture

When polyamides are exposed to water or a moisture-bearing atmosphere, they absorb water. This causes a decrease in tensile strength and an increase in flexibility. The reduction in strength depends on the amount of water that is absorbed, in equilibrium with the moisture level of the surroundings. For example, when nylon 6 is exposed to an atmosphere of 50% relative humidity, it will attain an equilibrium moisture content of 2.7% by weight. However, if immersed in water, it will gradually absorb moisture until saturation is reached. The moisture content at saturation is approximately 10%. This effect is reversible; i. e., the material can be dried and its strength regained. In general, it is necessary to vacuum dry at approximately 150°F to prevent oxidation which tends to embrittle nylon.

In Fig. 3 the hoop strength of ¼-in. OD tubing, extruded at two different bath temperatures, have been plotted against moisture content on log coordinates. The slopes are approximately linear between 1% moisture content and saturation which covers the range encountered in most applications. This means that in this range the relationship between hoop strength and moisture content can be expressed as:

$$H = \frac{K}{M^N}$$

where H = Hoop Stress, psi; K = Constant; N = numerical slope of the curve; M = Moisture Content, % of total weight.

One practical significance of this relationship is that it provides a convenient way of comparing the effects of other strength parameters. Thus, it might be possible to isolate the effects of other variables, such as ambient temperature and exposure to chemicals, by adjusting the test data on bursting strength to any desired moisture content.

Effects of Annealing

The mechanical properties of nylon 6 are known to depend on its crystalline structure and the degree to which crystallization occurs. In a molded or extruded object, crystallization depends on the rate at which the part is cooled from the melt. Crystallization can, however, be increased by annealing at an optimum temperature and, subsequently, cooling slowly. This will bring about an increase in tensile

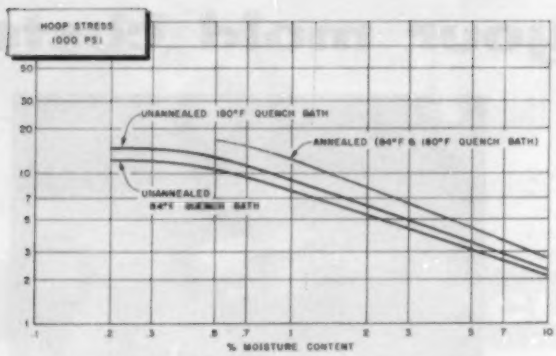

Figure 3. Hoop stress vs. moisture content ¼-in. OD x 0.020-in. wall tubing Plaskon nylon 8205.

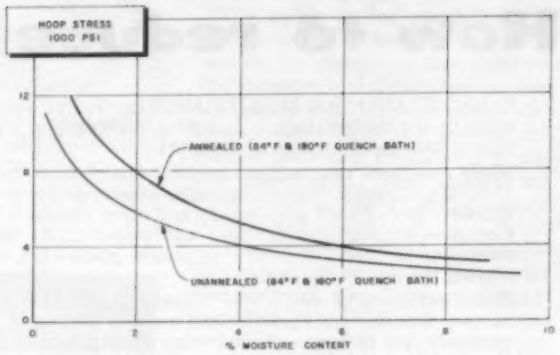

Figure 4. Hoop stress vs. moisture content ¼-in. OD x 0.030-in. wall tubing Plaskon nylon 8205.

strength and a decrease in flexibility.

Also compared in Fig. 3 is the hoop strength vs. moisture content relationship for the same tubing, annealed and unannealed. It can be seen that annealing produces a substantial increase in strength, but strength is still dependent on moisture content similar to unannealed tubing.

Effects of Bath Temperature

In the extrusion of nylon tubing the extrudate is quenched suddenly in a water bath in order to preserve the shape imparted by the die. Experiments have shown that raising the temperature of the bath tends to increase the strength of the tubing. Two explanations can be advanced to account for this:

1. The higher bath temperature decreases the rate of cooling of the tubing and promotes crystallization.
2. By keeping the tubing soft while it is drawn through the water bath, the higher bath temperature permits partial orientation because of the tension in the tubing.

Referring to Fig. 3, it can be seen that the burst strength of the ¼-in. OD, 0.020-in. wall tubings are significantly affected by the water bath temperature. The higher bath temperature results in higher hoop strength. Fig. 4 shows the plot, on rectilinear coordinates, of hoop strength vs. moisture content for ¼-in. OD, 0.030-in. wall tubing extruded at two different bath temperatures. In this case the bath temperature has no effect on the hoop strength of the tubing. There appears to be a limiting wall thickness above which bath temperature has very little effect on the properties of the tubing. The greater wall thickness impedes the transfer of heat to the coolant to the point where the temperature of the coolant has little effect on the rate of cooling. This same phenomenon occurs in the injection molding of nylon where the mechanical properties of heavy sections (over ¼ in.) are unaffected by mold temperature.

★ ★ ★

Physical Properties of Polyethylene–Acrylonitrile Grafts

W. Burlant and C. Taylor
Scientific Laboratory
Ford Motor Co.

Grafts of acrylonitrile to polyethylene prepared by the various techniques have been described, but little mention has been made of physical properties. In this laboratory, using the oxidation technique, these have been prepared; some properties are presented in accompanying table. The highest grafts (containing 220% acrylonitrile) are still films, but possess densities and softening points essentially those of polyacrylonitrile. The grafted films are brittle (elongations at and above 10% grafting for the 0.001 and 0.002" films, 5%), absorb somewhat more water than the untreated material (all grafts above 10% absorb about 1-2% water after 24-hour immersion at 25°C, while the blanks show no weight increase). In addition, a slightly modified falling sand abrasion test indicated that while 100 liters of sand failed to wear through the untreated 0.001" film, the 10% graft failed after 25 liters; the thicker graft materials lost 1-2% in weight after this treatment, but did not fail. Grafts containing greater than 10% acrylonitrile softened slightly at 134°C and exhibited the color changes of polyacrylonitrile as the temperature was raised to 250° C. After 300 hours in an Atlas X-W Weather-ometer, the grafts became more brittle than the control film, and aside from slight yellowing of the 200% grafts, no other changes were noted.

Wt. % of grafted monomer	Density[b]	Benzene permeability[c] gm/meter²/24 hr/mil	Tensile strength[d] psi
	0.001" Linear Polyethylene		
0	0.942	763	4002
10	0.067	—	4850
84	1.026	362	6483
125	1.053	—	7432
220	1.076	106	7940
	0.002" Linear Polyethylene		
0	0.944	264	4136
12	0.965	132	4780
60	1.015	86	5120
140	1.058	—	6950
214	1.076	64	7950
	0.003" Linear Polyethylene		
0	0.947	222	3850
10	0.958	81	5100
35	0.981	58	4800
90	1.021	—	6231
150	1.054	23	7825
220	1.083	—	8050

[a] Marlex 50 films (Phillips Petroleum Company); [b] Flotation method; [c] Slightly modified ASTM E96-53T; [d] Average of five values in each direction (av. of machine and transverse direction).

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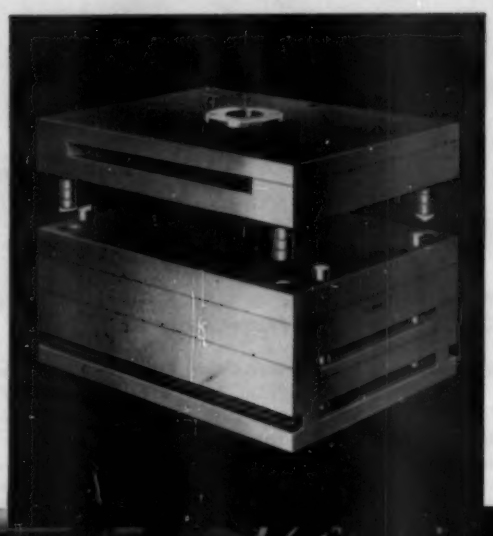

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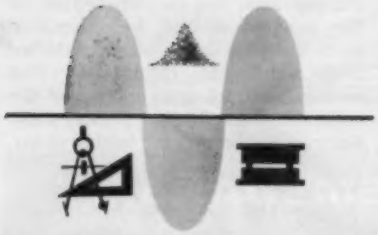

Edited by Louis Paggi, *Consultant*
E. I. du Pont de Nemours & Co., Inc.

MOLDING CYCLES

Selecting Plastics to Suit the Application

R. L. Miller

Sales Service Laboratory
Polychemicals Department
E. I. du Pont de Nemours & Co., Inc.

THE SUCCESS of the plastics industry, as with any industry, ultimately rests in the hands of the consumer. Satisfied customers are the basis for industry growth. The early period of exploration has given way to well engineered plastics products that offer the consumer greater values both in initial usefulness and long-term performance. It is essential that this constructive approach be continued to further the vigorous growth of our industry.

There is still a job to be done in selling the many potential customers on the proper use of plastics. One excellent selling tool is to assure that the plastic suits the application. It is the goal of this article to point out the several important factors that should be considered when making a material choice.

The fact that the term "plastics" means a family of distinct materials, just as "metals" in that industry, must be emphasized. It is as meaningless to say "it's made of plastics" as "it's made of metal." Nylon, for example is as different from polyethylene as iron is from copper. Making the proper selection of the plastic for a particular application can be as easy or as difficult as choosing the proper metal.

The many plastics materials available today offer a wide variety of properties from which correct selection can be made. Sometimes a single end use requirement is sufficiently important that the material to be used is practically dictated. For instance, of the thermoplastics, resistance to hydrochloric acid at high temperatures can be met only by the fluorocarbon plasties. Even then, choosing the best fluorocarbon must be resolved. For the most part, then, selection depends on a combination of properties that must be associated with the requirements of the application.

Requirements of the application may be determined by considering, first, the mechanical needs of the product, then, how the item is to be processed and, lastly, the economics of producing the part.

Mechanical Considerations

Each product requires elements of strength whether it be pure tensile, compression, stiffness, fatigue or impact, or a combination of these. Good design dictates a balanced use of these requirements. For instance, a plastics tumbler must not shatter when dropped; yet it need not resist crushing if accidentally stepped upon Stiffness of the tumbler is adequate if it resists collapsing when filled with liquid and held in a normal position.

Chemical resistance is an important requirement. Resistance to oxidation (air) and hydrolisis (water) at specific temperatures are basic properties of essentially every plastics material. Beyond this, the application may require resistance to environmental stress cracking, various acids and solvents. Polyethylene has excellent resistance to acids, but certain hydrocarbons will cause softening. Staining or outdoor exposure may be a problem. For outdoor exposure, weather resistant compositions should be selected.

The infinite color possibilities in plastics materials has played a large part in the growth of the industry. The styrenes, melamines and acrylics are but a few plastics whose excellent colorability has greatly enhanced their use. Included also under appearance requirements are such things as clarity, translucency, texture and gloss.

Other mechanical requirements which may need to be considered are electrical (insulators, coatings), frictional (gears, bearings), abrasion (dinnerware, wire coatings) and machinability.

Processing Requirements

Once the mechanical requirements of the product have been determined, processing needs may be explored. These needs will include such things as flow, ejectability, freedom from surface blemishes or voids, and thermal stability. While some latitude in processability is possible through material selection, there is no substitute for the skill and knowledge of the processor. Nor should product quality in terms of mechanical properties of the plastic be sacrificed merely to gain some slight improvement in processability.

The processor and plastics manufacturer have an interlocking responsibility. Good processing technique is required of the processor, while the manufacturer must supply a material having good processing characteristics commensurate with practical end use properties.

The shape of the product often determines the type of processing required. For instance, a large flat section like a refrigerator door liner is normally thermoformed. A product having complicated projection is molded, and long continuous shapes are extruded. Sometimes the number of parts to be produced will influence the type of processing, but more often volume affects only equipment size.

Economic Requirements

The overall economic picture is kept in view at all stages of product development; however, material or resin cost should not be considered until mechanical and processing requirements have been determined.

Resin choice on the basis of cost would appear to be relatively simple; the lowest price resin meeting the above mentioned reequirements would automatically be chosen. Many times, however, use of a

higher priced plastic having a greater number of desirable properties will actually cost less than a lower priced plastic. For example, when using the more expensive material, it may be possible to reduce the wall thickness of the part without sacrificing needed rigidity. Or in another instance, a business machine costing thousands of dollars may break down due to a 10-cent internal part made of an improperly selected plastic, and possibly entail a replacement cost of $50 to $150. A more expensive plastic that would last the life of the machine would actually "cost" less than the cheaper resin.

Selecting the Plastic

When these important requirements (mechanical, processing and economic) have been determined for the particular application, selection of the plastic to meet these requirements is then in order. Of course, no single plastic will have all the desired properties, processing characteristics and low price. Consequently, selection becomes a matter of choosing the plastic which best meets the needs of the application.

A good working knowledge of the important characteristics of each type of plastics will enable the processor or designer to consider immediately only those plastics that are actual candidates for the application. Beyond this, he can seek advice from specialists familiar with the plastics being considered. No one person can be expected to be adequately familiar with all the plastics available today.

The many excellent publications on plastics are good sources of useful information. Subscriptions to these periodicals are an inexpensive means of keeping abreast of our rapidly changing plastics industry.

Another good source of plastics information is the supplier. Each raw material supplier distributes reports, bulletins, product sheets and manuals describing in detail the physical properties and processing characteristics of his plastics. This information, along with the published articles, should be kept in a special file for immediate reference.

Testing

The last phase, and one of the most important in the procedure for selecting the proper plastic, is testing the final design. Prototypes of the product should be fabricated from the selected plastic and tested under end use conditions. Test should continue until success of the commercial application is essentially assured. Neglecting the testing phase, or performing it under non-representative conditions, can lead to unpleasant marketing experience. There is no substitute for product testing in determining how well the elements of design and material selection have been carried out in developing a new plastics product.

Conclusion

Improper choice of a plastic may result in costly revision of a development program such as retooling; if the product has been unsuccessfully marketed, the mistake is compounded. Instead of enjoying an increasing market acceptance, increasing resistance, doubly hard to overcome, may result. The continued cooperative effort by the designer, processor and materials supplier in selecting the plastic to suit the needs of the application will help to assure the healthy growth of our industry.

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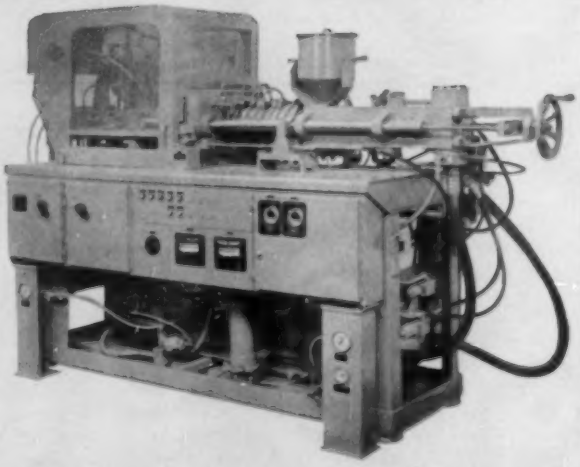

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Moslo Machinery Company

MANAGEMENT VIEWS

A Current Appraisal of . . .

Standardization in the Moldmaking Industry

I. T. Quarnstrom
Detroit Mold Engineering Co.

I. T. Quarnstrom, founder and President of Detroit Mold Engineering Co., is recognized as the originator of mold base standardization.

In 1932 he started Quarnstrom Tool Co., making custom plastics molds and die-cast dies. In 1942 he began his standardization program for plastics molds. Since then, the production of standard mold bases and component parts by D-M-E has expanded to include manufacturing plants in Detroit; Hillside, N. J.; Mt. Clemens, Mich., and Charlevoix, Mich.; with sales offices in Cleveland, Dayton, Chicago, Los Angeles and Toronto, Ontario.

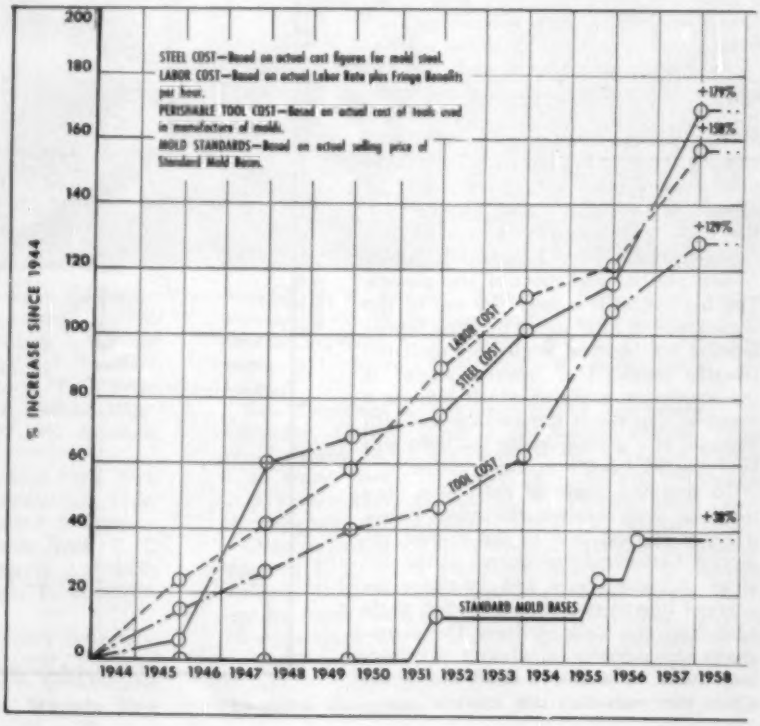
His efforts in standardization, both in products and in services to SPE and SPI, have been instrumental in accelerating the growth of the plastics industry.

ONE of the most important strides made in recent years concerning the future of injection molding was the formal approval of the SPI Machinery Standards on March 15, 1958. The real benefits of this long-awaited set of standards for the machinery manufacturers will not be felt for some time; however, it will eventually provide the basis for considerable savings for the entire plastics molding industry.

Taking part in the realization of this forward step for the plastics industry was a privilege for me personally. It was especially gratifying since the ground work laid in the field of mold base standardization played an important role in the formulation of the Standard Platen Specifications that were adopted. By mutual agreement of the machinery manufacturers, the approved standards went into effect officially on September 15th of this year. The timeliness of this action prompts me to make a brief appraisal of Standardization as related to the building of plastic molds.

The origin of Standard Mold Bases in 1942 was the forerunner of all later standardization in the mold building field. Prior to this date, everything that went into a mold, with the exception of the screws and dowels, was fabricated by the mold builder from raw steel. Today, it is conceivable that everything going into a particular finished mold is available as a standard stock item, with the exception of the cavities and cores. The contrast between what a moldmaker requires today and what he needed to complete a mold a short 15 years ago is quite startling. Looking at the shortened delivery requirements of many mold building programs of today, it is hard to conceive of the industry without the availability of standard mold components.

Yet, standardization of mold bases and component parts did not receive the immediate acceptance one might expect. While the need for standardization existed during the early formulative years of the plastics industry, the evolutionary process was not a natural one. It required constant revision, improvement and application before its practical usage had "arrived" and acceptance was achieved. One authority on stand-



ardization has explained that, "standardization can be undertaken successfully only when industrial development has progressed to the point where no considerable change takes place in the elements controlling the particular problem."

Enough water has flowed under the bridge, during the 15 years since the mold standardization program was started, to take a look at whether or not the economic aspects have been justified. The graph shown here pictures the price increase incurred by three of the major cost factors in the building of a mold. The graph quickly reveals how standardization of mold bases has enabled the assimilation of a major portion of the heavy cost increases in steel, labor and perishable tools.

The advantages of interchangeability can never be overstated. The replacement of mold parts after long service, at nominal cost and with a minimum of machine down time, has proved to be a real boon to the molder.

While these obvious benefits of standardization have been acclaimed time and time again, there have been many by-products of these basic benefits that are worthy of mention. They are:

1. The "release" of investment capital on the part of the moldmaker for equipment more vitally needed in the manufacture of cavities, cores and his other specialized requirements.
2. Standardization enables the buyer and seller to speak the same language and eliminate many misunderstandings.
3. It is one of the principal means of getting the results of research and development into widespread use in industry.
4. Experienced design engineers can devote more time to the creation and development of the specialized aspects of mold design.
5. In times of national emergency the availability of standard stock bases has proved instrumental in achieving accelerated production of critical goods in a short period of time.

What lies ahead in the way of standardization in the plastics molding industry? The major advances, as I see them, lie in improvements in quality, accessibility and still further economic gains through the use of more efficient manufacturing equipment. These advances, coupled with the future benefits that the SPI Machinery Standards will provide, promise moldmakers and molders even greater benefits than have already been achieved through standardization.

★ ★ ★

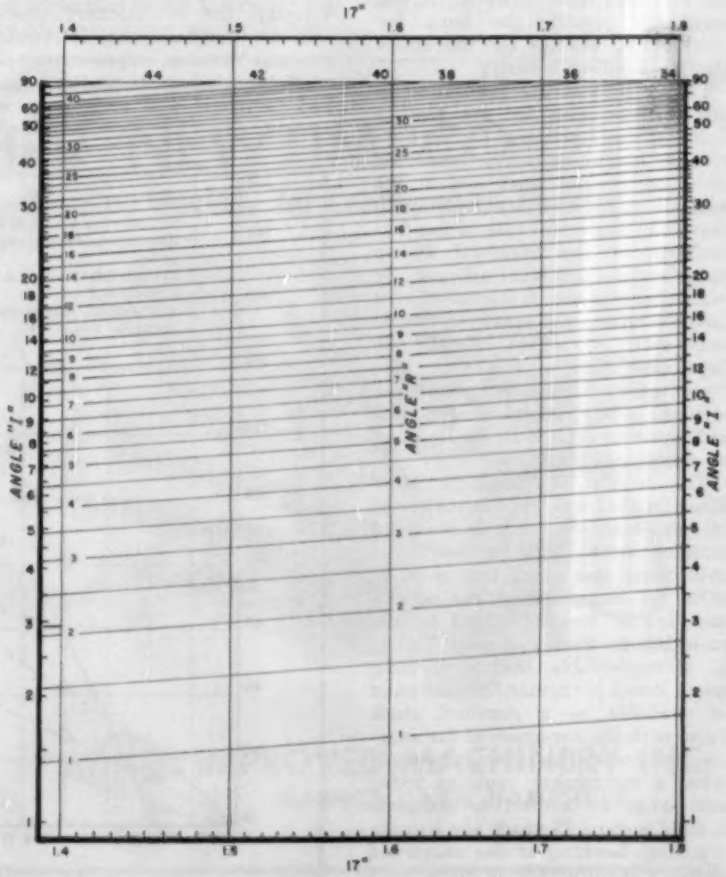
Solving Light Transmission Problems in Transparent Materials

R. R. Dixon
Refrigerator-Freezer Engineering Dept.
Westinghouse Electric Corp.

IN THE design of lenses, light covers, and other light refracting parts, use is made of the formula $\frac{\sin I}{\sin R} = n$, *where* n is the index of refraction. I is the angle of incidence of the light beam, measured from a line perpendicular to the surface of the refracting material, and R is the angle of refraction, measured the same way.

The accompanying nomograph was constructed to solve the equation above. For accurate work the values should be calculated, but for many applications, the nomograph is quite adequate. The index ranges from 1.4 to 1.8, which covers plastics and most of the glasses. The horizontal line near the top of the nomograph is intersected by lines representing the "critical angle" for each refractive index. This "critical angle" is the maximum angle at which light in a material can reach the surface and still emerge; at a greater angle the light will be reflected back into the material.

To find the angle of refraction of a material with known refractive index, draw a vertical line at the known index. A horizontal line drawn at the desired incident angle will intersect the vertical line to give the refraction angle read from the inclined lines. The nomograph also permits calculation of refractive index or angle of incidence, if the other two variables are known.



Edited by Thomas A. Bissell
SPE Executive Secretary

NATIONAL ACTION

Management of Your Society — SPE National Council

SPE Constitution and By-Laws designate the National Council as the governing body of the Society. 1958 Council is composed of 46 men —40 elected representatives of the Sections; 5 Councilmen-at-Large, consisting of the elected National Officers and immediate Past President; and the Executive Secretary, a non-voting member. Each SPE Section elects one of its affiliated members to serve as Councilman for a term of three years. Members of National Council have varied personal interests and in their business lives represent many facets of the plastics industry and government—research, design, development, production and sales.

Meetings

Regular meetings of Council are held quarterly for discussion of technical projects for SPE sponsorship; analysis of reports of technical and administrative committees; budget and fiscal analysis; and guidance of staff in solution of problems affecting the business management of the Society. During 1958, Council has been called upon to attend two special meetings. The first, in January, dealt with *Processing of Thermoplastic Materials*, Volume II of SPE Engineering Series, which will be published late this year. A second special meeting was required in September to review proposed revisions to SPE Constitution and By-Laws prior to submitting our new Constitution to the membership early in 1959 for ratification.

Other Responsibilities

In addition to meetings of Council, Councilmen attend regular meetings of their Sections to present National problems to Section Boards

(*Continued on page* 56)

1958 SPE National Council—Washington, D.C. Meeting, April 15, 1958

1st Row (L to R): M. Usab (proxy), Southern California; C. D. Kacalieff, St. Louis; G. P. Fong (proxy), Eastern New England; *G. P. Humphrey, At-Large, National Treasurer; *R. K. Gossett, At-Large, National President; *G. W. Martin, At-Large, National Secretary; *F. C. Sutro, Jr., At-Large, National Vice President; B. W. Nelson, Miami Valley; F. W. Reynolds, Binghamton; *P. W. Simmons, At-Large, Past National President.

2nd Row (L to R): J. R. Lampman, Central New York; E. C. Quear, Central Indiana; S. H. Greenwood, Philadelphia; R. B. Kirby (proxy), Upper Midwest; J. R. Johnson, Southeast New England; E. L. Larkin, New York; R. C. Smith, Detroit; P. G. Fleming, Kansas City; W. I. Pribble, Northern Indiana; D. W. Biklen, Newark; E. C. Moslo, Cleveland-Akron.

3rd Row (L to R): *T. A. Bissell, Executive Secretary; L. A. Bernhard, Manager, Administrative Dept., National Office; B. G. Achhammer (guest); K. A. Erwin, Kentuckiana; D. Mersey, Connecticut; A. W. Logozzo, Western New England; R. M. Stroman, Rochester; P. A. West (proxy), Milwaukee; *F. W. Reinhart, Baltimore-Washington; J. W. Lindau, Southern; H. S. Nathan, Buffalo; F. L. Fine, Chicago; J. L. Burnie, Ontario; C. E. Rhine, Editor, *SPE Journal*.

Councilmen not present when picture was taken: H. W. Kuhlmann, Central Ohio; J. D. Moore, Golden Gate; W. C. Conroy, Northwest Pennsylvania; T. Nakao, Osaka; B. V. Korry, Pacific Northwest; J. B. Schmitt, Pittsburgh; O. B. Yorker, Rocky Mountain; L. C. Williams, South Texas; M. J. Petretti, Southeastern Ohio; D. R. Bowlin, Toledo.

Changes in Council since April 15, 1958: I. J. Freeman replaced R. C. Smith (resigned), Detroit; C. B. Howard replaced L. C. Williams (resigned), South Texas; R. A. Jenkins, North Texas (New Section); W. F. Utley, Tri-State (New Section); M. F. Malone, Quebec (elected to fill vacancy.)

*Executive Committee

National Action . . .

(*continued from page 55*)

of Directors and to solicit Section opinions on Society management.

Councilmen may also serve as members or Chairmen of standing or special National SPE Committees. This year, members of council chair the following committees: Profession Activities Groups (Administrator); Inter-Society Relations (Administrator); Technical Committees (Administrator); Publications; Constitution and By-Laws; Finance; Membership and Institute Committee. Some Councilmen serve as Feature Editors, *SPE Journal.*

Only Councilmen may be elected as National Officers; each year Council elects four of its members for service in National Office.

Executive Committee

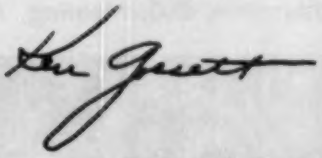
Council delegates to a committee of six of its members and the Executive Secretary decisions on business matters arising between Council meetings. The Executive Committee meets, on the call of the President, on the day prior to each meeting of Council and normally on four other occasions during the year. Executive Committee is not empowered to disburse unbudgeted funds, and all actions of this committee are subject to review by Council.

An Impression

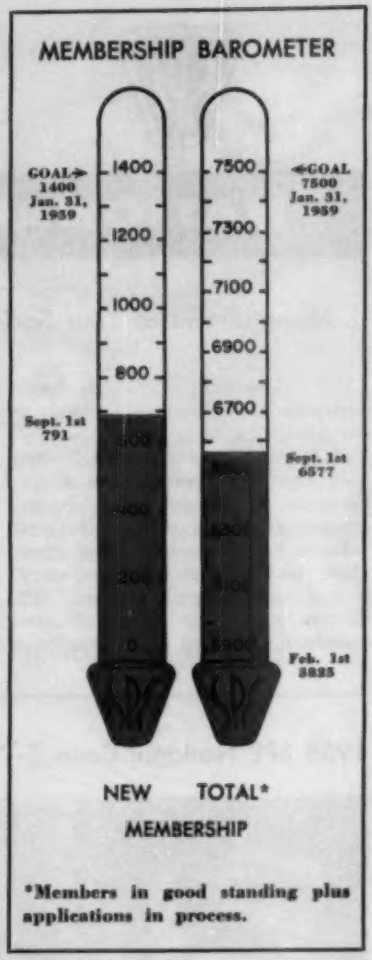
It has been my privilege to serve as a member of Council for the past three years. I have been, in this time, deeply impressed by the sincere interest of Councilmen in the affairs of the Society. These men give freely of their time and money for the Society in traveling to committee and Council meetings held throughout the United States and Canada. They make every effort to think objectively on each problem facing SPE, taking into account the opinions of the Sections they represent, but voting as they deem best for the continued growth of the Society and the plastics industry. National Councilmen accept the will of the majority as determined by ballot.

SPE Members have reason to be proud of the democratic body which is the National Council. Each member of the Society should consider carefully the responsibilities of service required of Councilmen in selecting men for service in the governing body of SPE.

Sincerely,



R. Kenneth Gossett
National President



***Members in good standing plus applications in process.**

Standards on Drafting for Plastics

Section 11 of the American Drafting Standards Manual, which deals with plastics, has just been published by The American Society of Mechanical Engineers. This is approved as an American Standard by the American Standards Association.

Designated American Standard Y14.11-1958, Section 11 is one of 17 sections of the Manual which, when completed, will provide the means for uniform drafting practices throughout the United States and most other English-speaking countries.

The purpose of Section 11 is to indicate basic preferred design and drafting practices specifically related to parts formed of plastics materials. To assist the designer and draftsman in the delineation of plastics drawings, a brief discussion of materials and manufacturing processes and operations has been included in the standard, together with design and drawing hints for parts formed from plastics of the molding and laminating design.

No attempt has been made to cover over-all product design. Tolerances are discussed only from a general standpoint. Typical drawing notes are shown which are commonly observed on plastics parts drawings. Methods of dimensioning of plastics parts have not been included in Section 11 because they are the same as for any other material, and are thus covered in other sections of the Manual.

Section 11 should prove invaluable in effecting a design that can be manufactured at the lowest possible cost. Since it correlates recommended practices of many molders and fabricators of plastics parts, the section should help reduce the number of changes required in drawings due to production problems.

Joint sponsors of all sections of the Manual are The American Society of Mechanical Engineers and the American Society for Engineering Education. The project is carried on under the procedures of the American Standards Association. Chairman of the entire project is Professor R. P. Hoelscher, head of the General Engineering Dept., University of Illinois. The Manual is correlated with a corresponding standardization of drafting practices in Great Britain and Canada.

Section 11—Plastics (Y14.11-1958)—of the American Drafting Standards Manual is available at $1.50 per copy from American Standards Association, 70 East 45th St., New York 17, N. Y., or from The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y.

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COMMITTEE REPORTS

PAG on Plastics in Electrical Insulation Holds Meeting in Cleveland at NCAEI

Twenty SPE members met September 4, 1958, during the National Conference on the Application of Electrical Insulation in Cleveland. Under the direction of PAG-PEI Chairman Max M. Lee, the group had an informal discussion and progress report on the work of the group since the January ANTEC.

It was proposed that a Regional Technical Conference centered on printed circuits and a specific type of encapsulation be considered for May, 1959. The recommended location is Pittsburgh. The Conference would depart somewhat from the traditional approach; it would seek to solve or propose solutions to several of the more important problems in the field by means of group approach.

The meeting served to remind the several task groups that work is to be done. With the 1959 ANTEC approaching, it is important that all available time be used.

Task Group Chairmen A. Ringwood and C. A. Harper reported directly on the progress of their groups. Others present represented most of the working Task Committees. It was stressed that only when sufficient data is truly available will many engineers consider plastics as an engineering material similar to wood and steel.

NCAEI Conference

Over 1500 people from all segments of the electrical insulation field attended the first National Conference on the Application of Electrical Insulation held in Cleveland, September 3-5. The conference was co-sponsored by SPE, AIEE and NEMA.

Highlights of the conference were the presentation of about 135 papers, forums following each session, and exhibits by insulation manufacturers. The papers, presented in four simultaneous symposia, were divided into four sections—Rotating Equipment, Transformers, Controls and Instrumentation, and Electronics. The broad scope of the papers appealed to all segments of the electrical insulation field.

Many papers were of special interest to the plastics engineer. Subjects varied from types of magnet wire enamels, insulating varnishes, encapsulating resins and molding powders to insulating films, tapes, laminates and printed circuits. Particularly noteworthy among the papers offering new technical data were: "High Temperature Varnish-Wire Enamel Systems" by R. B. Young and J. R. Learn; "Development and Application of Flexible Polyester Molding Material to Instrument Transformers" by H. F. Minter, R. R. Kelly and A. J. Palumbo; "New Extreme Temperature Silicone Encapsulants" by J. Ballen, R. L. Spraetz and M. F. Nelson; "Performance Properties of Industrial Laminates at High Temperatures" by Norman A. Skow; and "A Study of the Windability of Magnet Wire" by R. O. Welsz, M. V. Thierry and G. C. Martin.

Inter-Society Relations Committee

G. Palmer Humphrey, Administrator, reports that the Committee does not have a liaison chairman between SPE and the following societies:

The Electro-Chemical Society, The American Society of Safety Engineers, The American Institute of Electrical Engineers, The Armed Forces Communication and Electronics Association, The National Association of Professional Engineers. The American Society of Civil Engineers, The American Institute of Architects, The ASTM Committee D-9, and The Engineers Joint Council.

Any member interested in working with any of the above societies should contact Mr. Humphrey.

New Section Development Committee

Chairman Ross H. Dean reports that, as a result of excellent cooperation by SPE members and prospective members, the New Section Development Committee has been able to work with interested groups thus far in 1958 to establish a progressive and active SPE Section in North Texas, which encompasses the Dallas-Fort Worth area. The acceptance of the petition for membership as a new Section was approved for this group at the June 20th National Council meeting, and the Section is functioning very actively with regular meetings through the summer months. At the June 20th meeting Council also accepted a petition for the formation of a Tri-State Section in Evansville. This is a division of the Kentuckiana Section; the new organization was made with the full approval of the directors of the Kentuckiana Section in Louisville. This Section is also functioning actively and shows promise of sound growth and development.

Strong interest in the establishment of an SPE Section in Monterrey, Mexico, has been evidenced for some time and, pending further investigation, temporary approval has been granted by the National Council for the establishment of a Section in this city. Close communications are being maintained with this group to assist in its organization and development so that it can qualify as an SPE Section.

Active work is being conducted in Oklahoma for the establishment of a new Section in the Wichita-Tulsa-Bartlesville area; in New Mexico, in the Los Alamos area; in Florida; and in Western Michigan. The SPE National Office is assisting in circularizing interested persons in the plastics industry in order to determine the number and type of membership which can be expected. Preliminary investigation of these areas showed

strong interest and sufficient reasons for serious consideration of the establishment of SPE Sections, but further study was deemed advisable in order to assist in the formulation of these plans. We expect definite activity on the part of several of these prospects during the next few months.

After careful study by the Board of Directors of the Cleveland Section, full approval has been given for the establishment of a new Section in the Akron-Canton area as a division of the present Cleveland Section. Formation of a new Section was deemed advisable because of the geographical location, as well as of the growing interest in plastics in the Akron-Canton area.

In response to interest evidenced in the West Virginia, Baton Rouge, Madison-Rockford areas and in Argentina in the possibility of new Sections, correspondence has been maintained and contact established. Although still in the preliminary stages, these negotiations could result in future SPE Sections.

Contacts have been made with a new plastics organization in British Columbia, with the thought that SPE could be of assistance to the new group. This organization is considering association with SPE as a Section, and assistance and communications are being maintained.

In summary, it can be concluded that there are several areas in which sufficient interest has been established to justify active work on the part of the New Section Development Committee to formulate new Sections. It is the desire of the Committee to form Sections which will be of the highest possible benefit to the membership, with our goal not being solely to establish Sections in quantity. Because of the interest shown in each area, we feel that our Society can continue to grow and develop, not only by increased membership, but also by the addition of new Sections located strategically throughout the country in order to serve the plastics industry more adequately in the technical phase of its work. This is the sole goal and responsibility of the New Section Development Committee as it makes its plans for the remainder of the year.

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TECHNICAL MEETINGS CALENDAR

15TH ANTEC

January 27-30, 1959, The Commodore Hotel, New York City. Sponsored by the Newark and New York Sections.

1958 RETECS

EPOXIES—October 21, 1958, Curtis Hotel, Minneapolis, Minn. Sponsored by the Upper Midwest Section. For information write to Russ Kirby, Minnesota Mining and Manufacturing Co., 900 Farquier, St. Paul, Minn.

PLASTICS IN ELECTRONICS—October 24, 1958, Stanford Research Institute, Menlo Park, Calif. Sponsored by the Golden Gate Section. For information write to Julius W. Palen, Lenkurt Electric Co., Inc., San Carlos, Calif.

ADVANCES IN INJECTION MOLDING—November 6, 1958, Sheraton Hotel, Philadelphia, Pa. Sponsored by the Philadelphia Section. For information write to Edward Fitzpatrick, F. J. Stokes Machine Co., Olney Post Office, Philadelphia, Pa.

PLASTICS TRENDS IN BUILDING AND CONSTRUCTION—November 13, 1958, Ambassador Hotel, Los Angeles, Calif. Sponsored by the Southern California Section. For information write to John Delmonte, Furane Plastics, Inc., 4516 Brazil St., Los Angeles, Calif.

1959 RETECS

(Scheduled before June 1959)

PLASTICS IN THE SHOE INDUSTRY—April 21, 1959, St. Louis, Mo. Sponsored by the St. Louis Section. For information write to Robert S. McDorman, Plastics Molding Co., 4211 N. Broadway, St. Louis, Mo.

PLASTICS IN THE METAL INDUSTRY—May 7, 1959, Penn-Sheraton Hotel, Pittsburgh, Pa. Sponsored by the Pittsburgh Section. For information write to John Parks, Hydraulic Press Mfg. Co., 512 Empire Bldg., Pittsburgh 22, Pa.

SECTION MEETINGS

BALTIMORE-WASHINGTON — October 14, 1958, Rolling Inn, Baltimore. "Plastics in Electronics" will be the subject of a talk by W. R. Cuming, Emerson and Cuming, Inc.

CLEVELAND-AKRON — October 20, 1958, Cleveland Engineering and Scientific Center, Cleveland. The subject of the meeting will be vinyls.

NORTHWEST PENNSYLVANIA—October 23, 1958, Penn Laurel Motel, Warren, Pa. William Kriner, Manager, Plastics Div., Hydraulic Press Mfg. Co., will speak on "High Speed Molding Through New Concepts in Preplasticizers." SPE National Treasurer G. Palmer Humphrey will give a short, informal talk on the goals of the Society.

WESTERN NEW ENGLAND—November 5, 1958, Bradley Field Terrace Dining Room, Windsor Locks, Conn. Irwin Lubalin, Shaw Process Development Corp., will speak on "Shaw Process Cast Cavities." Thomas Larkins, Elox Corp. of Michigan, will speak on "Elox Cavities" and show a film.

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ABOUT MEMBERS

George W. Martin, SPE National Secretary and president of Holyoke Plastics Corp., announces that on September 1, 1958, his firm changed its name to Holyoke Plastics Co., Inc., under a new corporate charter. The company is no longer a subsidiary of Noma Lites, Inc. There will be no change in management or method of operation. The immediate expansion program, however, includes two new divisions—a phonograph record pressing division and a resin compounding division. Mr. Martin is a member of the Western New England Section of which he was President in 1954. He is presently a member of the National Executive Committee, Councilman-at-Large, and Administrator, Administrative Operating Committees.

G. W. Martin

F. W. Reinhart

Dr. Frank W. Reinhart, Chief, Plastics Section, National Bureau of Standards, has been appointed a member of the Administrative Committee on Standards of the American Society for Testing Materials. He has also been made a member of the Materials and Testing Standards Board of the American Standards Association. Dr. Reinhart is Past National President of SPE, National Councilman from the Baltimore-Washington Section, Administrator of the Professional Activities Groups, and a member of the SPE Executive Committee. Among other societies of which he is a member are the American Chemical Society and the SPI.

Robert A. Karasek announces the incorporation of a new firm, Custom Engineered Plastics Co., Crestwood, Mo. Mr. Karasek, president of the firm, has been in the injection molding business since 1938. He is Secretary of the St. Louis Section of SPE.

Iver J. Freeman, Detroit Section, has started his own business, Freeman and Co., in Pleasant Ridge, Mich. The new firm offers a complete line of plastics machinery, equipment and engineering, and is exclusive representative of Watson-Stillman Press Div., Farrel-Birmingham Co., Inc., and Van Dorn Iron Works in Michigan and in the Toledo area. Mr. Freeman was associated with Reed Prentice Div., Package Machinery Co., for over twelve years, and was, until recently, Western Sales Manager. He is presently National Councilman from the Detroit Section, of which he is past president, and Chairman of the SPE Sections Committee. He served on the Executive Committee of the 14th ANTEC. Mr. Freeman's father, **Iver G. Freeman,** has also resigned from Reed Prentice to be associated with Freeman and Co. He has established a machinery sales and engineering office in Worcester, Mass. He is a member of the Pioneer Valley Section of SPE.

I. J. Freeman

A. S. Backus

Alfred S. Backus of the Newark Section has recently been appointed director of Mycalex Electronics Corp. and Mycalex Tube Socket Corp. Mr. Backus spent 20 years working with glass-bonded mica, first as foreman in charge of production at General Electric Co. In 1944 he joined Mycalex as plant superintendent, later became plant manager and works manager, and recently was promoted to acting general manager—the position he now holds in addition to his new duties as director.

William A. Messina has been appointed vice president and general manager of Wilson Plastics of Ohio, Inc. Mr. Messina was formerly technical representative for Bakelite Co., and prior to that was an instructor of engineering drawing at Cornell University. He is Vice President of the Cleveland-Akron Section of SPE.

W. A. Messina

Alex Sacher

Dr. Alex Sacher has accepted a new position as vice president of commercial development with Hudson Pulp and Paper Corp., New York. Dr. Sacher will be responsible for planning diversification and extension of product lines. He was formerly technical director of Standard Insulation Co. A member of the New York Section of SPE, Dr. Sacher is Program Chairman for the 15th ANTEC and Chairman of the SPE Reinforced Plastics PAG.

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Eighth National Plastics Exposition:

Plastics for Profit

Sponsored by The Society of the Plastics Industry, Inc.
International Amphitheater, Chicago
November 17-21

The largest and most diversified array of new products, machines and materials ever displayed simultaneously by the plastics industry will be introduced at the Eighth National Plastics Exposition in Chicago.

The wide diversity of items displayed at the Exposition will demonstrate that plastics is progressively extending its advantages and benefits to an ever-broadening range of users.

In an era marked by narrowing profit margins, every echelon of management is vigorously seeking, testing and employing materials and methods capable of keeping production costs within profitable bounds without sacrificing quality and performance. Since this search for cost-saving materials and methods is directed at the executive level, the National Plastics Exposition will naturally merit and receive the personal attendance and attention of top management, as well as executives and department heads responsible for design, engineering, processing and sales.

More than 200 comprehensive exhibits at the NPE will demonstrate that all segments of the plastics industry in the past two years have accelerated the research and development programs, continuously improving their production machinery and methods and extending the advantages of plastics to more users and broader markets.

Survey of Exhibitors

A preliminary survey among 205 companies exhibiting at the Exposition reveals that 86 exhibitors will show more than 200 new plastics products, machines, materials and related technical processes and services. According to John J. Bachner, Chairman of the Exposition Committee, the survey indicates that plastics research has produced more new products, applications and equipment during the past two years than in any similar period of the industry's 90-year history.

The survey was conducted to illustrate the recent competitive progress of plastics from the standpoint of their manufacturing economy, as well as their contributions to processing efficiency and product quality improvement. It revealed a broadening array of examples in which plastics have wholly or partially replaced other materials because of attractive cost savings provided by plastics materials and processing methods.

Examples most frequently mentioned were in this order: industrial equipment and components; automotive parts and components; appliance components; housewares; commercial packaging and industrial containers; portable TV and radio cabinets; boats and a wide range of marine hardware and accessories; electrical components; building materials; aircraft and missile components.

Reduced overall production, handling, shipping and maintenance costs, consistent with comparable quality, have been the principal custom considerations in about 50 percent of the new plastics applications coming into general manufacturing use since the previous NPE two years ago. Some exhibitors indicate that the more attractive costs of plastics and the economies afforded by plastics fabrication and production machinery and methods were the principal factors in from 80 to 90 percent of the new plastics applications since 1956.

Competitive marketing advantages made possible by proper application of plastics, together with the wider design freedom permitted by plastics, influenced a large percentage of new manufacturing uses over the past two years. Lower handling and shipping costs have also been important factors.

The growth of new industrial applications since 1956 has been stimulated not only by accelerated development and perfection of new and highly versatile raw materials, but also by increased technological knowledge among machinery and tool makers, molders, extruders and other major segments of plastics manufacturing. New uses of plastics in the past two years were largely influenced by the ability of plastics to help the manufacturers maintain the same product quality as obtained with former materials at lower costs or achieve better quality at the same costs.

Tickets and Registration

The Exposition, and the Annual National Plastics Conference which is held during the same week at Chicago's Hotel Morrison, will not be open to the public. Tickets for the Exposition are available from any exhibiting company or from the SPI to companies who are present and potential users of plastics.

Individuals wishing to attend the Conference may do so by registering. Leaders in the plastics industry and the industries and organizations it serves will review two years of progress in plastics.

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SECTION NEWS

Pacific Northwest

Injection Molding At Kodak Park

R. A. Fulton

The September meeting was held in the Flamingo Room of the New Washington Hotel. It was called to order by Section President Leo Siers. Attendance was approximately 40 members and guests. The features speaker was L. A. Ulmschneider of Eastman Kodak who showed a movie on automatic molding. The film illustrated mold construction, gating and knock-out techniques used by Eastman; safety features necessary for automatic injection molding; and construction of three types of heating cylinders and spreaders for obtaining optium automatic molding.

The next regular meeting is scheduled for October 17 in Portland, Oregon.

Pioneer Valley

Estimating Costs of Injection Molding

G. E. Berlyn

The Section was fortunate to have SPE National Secretary George W. Martin speak at the September meeting. In his talk on "Progress and Goals of Our National Society," he stressed the lack of communication from the National to Regional levels of SPE and pointed out the steps taken to correct it. He spoke of the development and growth of PAG and the fine work being done by the Constitution By-Laws Committee. Goals have been set to increase membership to 1400, and student and junior memberships are being investigated.

Technical speaker of the evening was Clifton J. Cowan, president, treasurer and general manager of Cowan Boyden Corp., Providence, R. I. His subject was "A Realistic Approach to the Estimating of Injection Molded Parts with an Analysis of Hidden Overhead Costs." He presented the group with a unique and comprehensive estimate work sheet which he uses in his business, and explained how he apportioned his molding labor burden and finishing labor burden, giving insight into his system of calculating costs and profit.

North Texas

Radiation and Plastics

Dave Daniels

The August meeting was held at Western Hills Inn between Dallas and Fort Worth. The speaker of the evening was Paul M. Cook, president of Raytherm Corp., Redwood City, Calif. Mr. Cook, a graduate in chemical engineering from MIT, was formerly head of the Radiation Laboratory of the Stanford Research Institute. He gave an interesting talk on the problems of radiation and plastics entitled "Recent Advances in Irradiated Polymer Systems."

Western New England

Our Dynamic Industry

C. Judd Holt, Jr.

The September meeting was held at the Bradley Field Terrace Room in Windsor Locks, Conn., which has been designated as the Section's regular meeting place for the new season. It was attended by 63 members and guests.

The speaker of the evening was Robert R. Lawrence, manager of research planning for Monsanto Chemical Company's Plastics Div. Dr. Frederic J. Locke, also of Monsanto, was Technical Chairman.

Section President Richard J. Plichta opened the meeting by introducing officers, directors and committee chairmen for the new season. He announced that on July 1 the section had 233 members and an additional 10 applications were being processed.

Mr. Lawrence spoke on "The Dynamic Plastics Industry." He traced the growth of the industry from infancy into manhood and described how it is changing in terms of materials, equipment and markets.

Ontario

Course on Plastics

Harry Watson

The Ontario Section is going ahead with plans to establish an academic course on plastics. This course will likely be of two years duration. It will be given on two evenings a week during the evening spring and fall terms at a Toronto school or university, still to be decided. The course is expected to begin in January.

At the September meeting the Section's Board of Directors appointed Barney Danson to head a committee on starting the course. The committee will attempt to draft up a plastics curriculum and decide such matters as location of classes, dates and fees. The course is expected to be presented in two phases —basic characteristics of plastics and fundamentals of plastics processing.

Cleveland-Akron

Packaging

M. Krajcik

The September meeting, held in new quarters located at the Cleveland Engineering and Scientific Center, was opened by Section President William D. Martin. Mr. Martin introduced SPE Past President Peter W. Simmons who gave a short talk outlining the aims of SPE for the coming year.

The speaker of the evening, James C. Brunner of Monsanto, gave an interesting talk on plastics in the packaging industry. He presented data to show past progress in this field, and pointed out that with improvements and modifications in wrapping machinery, plastics have a bright future in packaging.

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Building Research Institute Conference:

Field Applied Paints and Protective Coatings

Shoreham Hotel, Washington, D. C.
December 3-4, 1958

A research correlation conference, sponsored by the National Paint, Varnish and Lacquer Association and the Painting and Decorating Contractors of America, will present the newest developments in paint technology, advances in application techniques, and analyses of what's ahead in the production and use of paints and protective coatings of all types.

Wednesday, December 3

Registration—8:30 A.M.

Morning Session—9:30 A.M.

Conference Chairman: Harry Ross Young, *Market Development Supervisor, Finishes Div., E. I. du Pont de Nemours and Co., Inc.*

Introduction
"Paints and Coatings in Use Today"—Dr. Wouter Bosch, *Prof. of Chemistry, School of Mines and Metallurgy, University of Missouri.*

"Methods of Application and Surface Preparation"—Jack Zucker, *The Shatz Paint Co.*

Paints and Coatings for the Interior of Buildings
Chairman: B. F. Ames, *Vice President, Plextone Corp. of America.*

"Deterioration of Paints and Coatings"—Sidney Lauren, *Manager, Technical Service, Surface Coating Emulsions, Reichhold Chemicals, Inc.*

"Paints for Walls and Ceilings"—P. C. Herzog, *Manager, Trade Products Laboratory, The Glidden Co.*

"Paints and Coatings for Floors and Decks"—*Speaker to be announced.*

"Paints for High Humidity Service and Mechanical Equipment"—C. W. Shay, *Technical Advisor, Trade Sales Finishes Div., E. I. du Pont de Nemours and Co., Inc.*

Luncheon—12:30 P.M.

Afternoon Session—2:00 P.M.

Paints and Coatings for the Exterior of Buildings

Chairman: Charles E. Loucks, *Technical Director, National Paint, Varnish and Lacquer Association.*
"Common Deteriorating Influences and Effect of Construction Details Upon Performance of Finishes"—John C. Moore, *Paint Consultant.*

Paints and Coatings for Various Exterior Construction

"Masonry and Concrete Substrates—Gerould Allyn, *Rohm and Haas Co.*

"Wood Substrates"—Sid Wertham, *Products Application, New Jersey Zinc Co.*

"Metal Substrates"—Dr. Arnold J. Eickhoff, *National Lead Co.*

"Bituminous and Miscellaneous Substrates"—*Speaker to be announced.*

Thursday, December 4

Registration—8:30 A.M.

Morning Session—9:00 A.M.

Special Paints and Coatings for Industrial Requirements

Chairman: R. L. Norum, *Eastern Zone Manager, Bakelite Co.*

"High Humidity Applications"—Merton E. Williams, *President, The Wilbur and Williams Co.*

"High Temperature Applications"—Milton A. Glaser, *Vice President and Technical Director, Midland Industrial Finishes Co.*

"Severe Chemical Exposure Applications"—Kenneth Tator, *President and Director of Research, Kenneth Tator Associates.*

Color with Paints and Coatings

Chairman: W. L. Hensley, *Group Leader, Surface Coating Group, American Cyanamid Co.*

"Functional Use of Colors"—Faber Birren, *Color Consultant, Faber Birren Co.*

"Effects of Color on Paint and Coating Performance"—W. G. Vannoy, *Pigments Technical Service Laboratory, E. I. du Pont de Nemours and Co., Inc.*

Luncheon—12:00 Noon

Afternoon Session—1:30 P.M.

Economics of Paints and Coatings

Chairman: Francis Scofield, *Chief, Technical Div, National Paint, Varnish and Lacquer Association.*

The Future of Paints and Coatings

Chairman: Richard D. Drubel, *Coatings Technical Service, Dow Chemical Co.*

"For the Paints and Coatings Industry"—Dr. J. S. Long, *Prof. of Paint Technology, University of Louisville.*

"For the Construction Industry"—Leonard G. Haeger, *Architectural and Building Consultant.*

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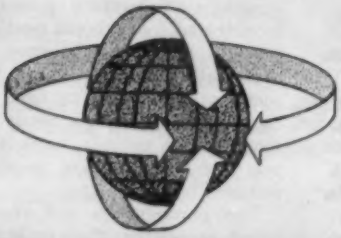

PLASTICS AROUND THE WORLD

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ITALY

POLIPLASTI
May-June, 1958
Abstracter: Alfred L. Alk

The Use of Polyester Resin as an Encapsulating Medium—Paolo Bonardi

Directions are given for mounting specimens in polyester resin. Solutions for drying and preserving floral exhibits, procedures for preparing inanimate samples, types and amounts of catalysts required and the treatment of the embedment after gelation are covered in detail.

Rilsan: The New Polyamide Resin for Injection Molding and Extrusion—Enrico Crosio

Rilsan is light; specific gravity is 1.04. It fuses at 186°C and can be used indefinitely in the range —50° to 100°C. Other properties are presented in detail. Like other polyamides, it must be carefully dried before use and is sensitive to local overheating.

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FRANCE

L'OFFICIEL DES MATIERES PLASTIQUES
April, 1958
Abstracter: Alexander Baczewski

Astronautics and Plastics—N. Dejarme

Propellants which are highly corrosive (e.g. fluorine) or which decompose easily (hydrogen peroxide) necessitate the use of plastics materials. Fluorinated polymers, polyethylenes and butyl rubbers have been recommended. In addition to the primary advantages, the low specific gravity of these materials allows a larger pay load by reducing the overall weight of the device. When such materials are laboratory tested, large variations in temperature, cosmic and ultra-violet radiation must be taken into consideration.

The Use of Cellulose Acetate Based Materials—V. Plasmat

The importance of conditioning cellulose acetate is stressed, and the differences between sheeting from various manufacturers are pointed out. Speed and teeth per inch of band or circular saws are given. The author recommends the dimensions of punches, the speed and the angle for lathe operations. Sanding should be done with carborundum only on a wheel having a tangential speed of 6000 fpm.

Formulations for dip-polishing are given. These are mainly mixtures of active solvents with water or gasoline. Cellulose acetate may be shrunk on mandrels, stamped, embossed or vacuum formed. Solvent compositions for gluing are given; usually acetone and some less active solvents are used to prevent buckling. Heavy cellulose acetate plates can be used as window panes but neoprene gaskets have to be used in order to make up for expansion and contraction.

Certain Aspects of the Fabrication of Plastic Masses Based on Cellulose Acetate—Jean Delorme

Plasticized and light stabilized cellulose acetate is masticated in the presence of solvents, sheeted out and laid up to the correct thickness. Such blocks can be sliced like nitrocellulose. The cut sheets are conditioned and dried. The manufacture of sheets, either blown or extruded, and of molding powders in the presence of latent solvents or water are described.

Recent Advances in the Fabrication of Plastics Foams—H. Neychen

This article is an abstract of information given by several leading manufacturers of base materials for foamed plastics. Polyurethanes, vinyl, urea formaldehyde and silicone foams are described. Advice is given for re-use of polyurethane scrap.

Wood Agglomerates and Laminates—P. Dalloz

Practice data of a Yugoslav wet process and a German dry process for manufacture of wallboard are given. Both processes contain resins and paraffin. Weather-resistant buildings are constructed from plywood bonded with urea, melamine or phenolic resins.

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GREAT BRITAIN

BRITISH PLASTICS
April, 1958
Abstracter: Evert A. Mol

Some Aids to the Design of Dies for Plastics Extrusion, Part. I—D. J. Weeks, Ph.D.

To prevent surprise in the design of extrusion machines and dies, it is necessary to predict approximately the pressures that will prevail. The pressures will, of course, depend on the viscosity of the material and the shape of the die, but neither of these two factors can be defined simply.

The viscosity of a plastic melt not only changes with temperature but also with shear rate, purely non-Newtonian flow is the exception rather than the rule. In the table the author presents the pressure drops that can be expected when a plastic melt flows through a channel of various shapes. The pressure drops are given for purely Newtonian liquids and for liquids that can be described by the so-called power law.

In the power law the shear rate is no longer directly proportional to the shear stress but it is proportional to the shear stress brought to the nth power. The coefficient n is a characteristic property of each plastic and for a purely Newtonian liquid would be equal to 1; it is usually of the order of 2 to 3. Very often the correction caused by the power law does not justify the extra work involved in calculating the power law pressure drop.

The article is very readable in that the basic mathematics are given

but one does not get lost in a set of complicated derivations. It is easy to plug in the constants of the plastics under consideration and to at least end up with an approximate value for pressure losses and power consumption. It is an interesting fact that the work done at Imperial Chemical Industries so closely parallels the work done by Tordella et al. at E. I. du Pont de Nemours & Co., Inc.

Plastics in the "Britannia"—

This is a well-illustrated description of the many and varied applications of plastics in the new turboprop airliner built by Bristol Aircraft, Ltd. A glance at the tabulation of applications of the different plastics in the article is enough to convince the reader that the aircraft industry is an important outlet for plastics of all kinds. The Brittania uses: rigid PVC, plasticized PVC, PVC-coated fabrics, polyurethane foams, polyester-glass laminates, urea formaldehyde resins, nylons, cellulose acetate butyrates, acrylics, polyethylenes, melamines, and epoxies. This seems to cover the field rather thoroughly.

The most important uses in terms of volume are the heat and sound insulations, air-conditioning systems with their complicated duct work, the wires and cables mainly in PVC, radar and deicing equipment, piping, bulkheads and doors.

Independent Research Laboratories Develop Two Styrene Copolymers—

A copolymer of styrene and alpha-methylstyrene known as Polectric SM 11 has been developed with a softening point of about 130°C. Maximum continuous temperature for most applications is not less than 120°C.

Injection molding temperature is 260°C (polystyrene is 210°C.) Polymer can be converted to thin film. It is a thermoplastic.

A thermosetting copolymer based on styrene and divinylbenzene is known as Lucentine. It has a dielectric constant and power factor similar to polystyrene, and has good heat resistance of 140°C. The material is supplied cast in rods and sheets and can be machined readily.

Several grades are available with different softening points and hardness. The article gives no information on other electrical properties. It indicates no mechanical faults developed by insertion into oils, petroleum spirits and similar solvents.

Fabrication of Rigid PVC—

The Italian firm of Mazzucchelli Celluloide has issued a booklet on properties and application of PVC covering the usual machining operations and the joining of PVC pipe. It discusses details of making socket joints, threaded joints, joining PVC tubes to metal and other materials, flange joints and expansion joints.

A service is performed by defining the limits for PVC applications. Even some apparently undesirable properties may be put to good use. The report is illustrated.

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PLASTICS
July, 1958
Abstracter: Alfred Rexer

Vacuum Forming and its Applications—R. W. Harwood

This two-page article describes and illustrates vacuum forming and its uses for domestic, industrial, packaging and advertising applications.

Capacitative Heating of Dielectrics in H. F. Fields—

This is a short article describing the methods of bonding synthetic materials using high frequency electric fields.

The Use of Plastics in Marine Applications—

Six lectures in the use of plastics in marine applications are highlighted.

The Use of Plastics in the Button Industry—P. Vaughan

The principal materials used in button manufacture are considered with some reference to quality, decorative effect, and the reason for their selection and continued use.

★

RUBBER AND PLASTICS AGE
May, 1958
Abstracter: Walter A. Gammel, Sr.

Testing of Ziegler-Polyethylene Pipes—Dr. K. Richard, G. Diedrich and E. Graube

Mechanical properties of thermoplastics are time dependent. Tests running continuously for 30,000 hours indicate that high density polyethylene pipe should be satisfactory for service at 68°F at allowable maximum stress of 710 psi for 50 years.

Long-time rupture strength will be affected by ambient medium and liquids being transported. Creep tests following the Bell Telephone test method cannot be used advantageously. The tests must extend over longer periods; with the Bell test the initial stress is gradually reduced by relaxation.

The photographs and charts are worth reviewing. They include creep rupture at 68°F (pipe with inside pressure), creep rupture vs. temperature (to 176°F) for high and low density polymers, and orientation vs. creep rupture.

★

GERMANY
DER PLASTVERARBEITER
March, 1958
Abstracter: Leo Fischer

The Practice of Sintering—E. Gemmer

Sintering can be carried out with any substance which will stand the high heat required. It is most important that the object not be zinc- or chrome-plated, and that it has no oil, lacquer or wax on it. Steel should be no thinner than 0.8 mm, the lighter metals 1.5 mm. In most cases it is best to sandblast the object. However, numerous chemical treatments have been perfected.

The most important element in sintering is prewarming. Temperatures range from 180° to 380°C, and in some cases up to 500°C, depending on the thickness of metal, but chiefly on the plastics and the size of the particles. The most practical method is heating at 600° to 900°C for 30 to 100 seconds and then coating immediately. It generally takes 3 to 30 seconds of immersion to complete coating. Post sintering is often desirable.

Polyethylene has to be cooled slowly. Polyamides, however, can be quenched in oil or water.

The sintering technique was developed chiefly in Germany based on GP 933019.

April, 1958
Abstracter: Leo Fischer

Injection Molding of Hostalen—Dr. A. Schley and Dr. A Fischer

This article discusses the injection molding of a linear polyethylene with specific gravity of 0.94. An interesting test mold for flow properties is illustrated. It consists simply of a spiral cut into a mold. The

length and uniformity of the plastics injected into the mold gives an excellent picture of the flow characteristics. The authors state that the lowest possible temperature consistent with adequate flow should be used because the low viscosity reduces formation of crystals. Problems of shrinkage and design are discussed.

May, 1958
Abstracter: Leo Fischer

Problems and Effects of Metering Thermoplastics in Intermittent Production—Walter Mink

Metering problems arise in thermoplastic molding because an exact amount of molding powder must be metered into the cylinder at each action of the plunger. Five forms of granules are illustrated. Volumetric measurement is never reliable, and is responsible for much poor molding. The author describes the mechanism for volume metering in detail with working drawings of a very exact weighing device which is completely automatic.

★

KUNSTSTOFFE-RUNDSCHAU
April, 1958
Abstracter: Leo Fischer

Hard Fiber Boards—H. Zickel

The use of phenol-cresol-formaldehyde system with fibrous materials is discussed. The applications are mainly in mechanics. Advantages are corrosion resistance, abrasion resistance, ease of work and dimensional stability. These materials have also been used structurally.

Impregnated Paper and Other Laminated Materials of the Electrotechniques—Dr. W. Ploch

The author discusses the various resins used in paper laminates. In all cases, high resin content produces low water absorption and high electrical insulation, but low mechanical strength. However, qualities that hold for small tubing or blocks are not necessarily the same for large or heavier tubing and blocks.

After outlining the usual application of paper laminates, the article discusses new developments such as use in high tension techniques: laminates with low electric potential to be used under tropical conditions for long distance telephones; and copper clad laminates for printed circuits. Paper laminate tubing has been used for oil conduits.

The newer resins used in paper laminates are melamine, silicone, polyester and epoxy. These have various advantages and disadvantages, but the epoxies are the best of all resins for most applications. The author devotes several pages to the epoxies and makes extensive comparisons.

May, 1958
Abstracter: Leo Fischer

Influence of Powdered Fillers on Polyesters — Edith Behnke

Fibers in combination with polyesters have the function of mechanically strengthening the hardened resin. Powered fillers have other influence on the end product. This article covers the latter.

Aluminum and bronze powders are unsuitable as fillers in polyesters.

Viscosities can be effected in a range where 60% of powdered inorganics do not affect the viscosity, whereas 2% of certain silicates increase viscosity to a paste. Some fillers cause considerable thixotropy, whereas bentone creates a putty.

Pot life is poorly affected by graphite. Some kaolin clays, especially in Germany, are too impure and prevent air gelation; whereas porcelain clay has no effect. Some chalks hasten gelation; pigments may affect gelation and cure either way.

Shrinkage is generally reduced by addition of fillers. Tack free surfaces can be obtained by adding bentone, paraffin and other fillers.

Styrofoam Panels as Expendable Molds — K. H. Krause

This article explains the practicality of using styrofoam as forms for cement casting, thus making a low cost mold. The foam acts as an insulator since it is left in place. Problems are discussed and methods of handling foam panels are suggested.

★

KUNSTSTOFFE
April, 1958
Abstracter: Charles S. Imig

Processing and Manipulation of Acrylic Materials—Dr. P. Weisert

This article is a comprehensive review of polymethyl methacrylate. Individual attention is paid to dif-

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ferent processing techniques in addition to a rather complete discussion of applications.

Acrylic Molds for Casting Small Components in Epoxy Resin—Walter Stumpf

A method is described whereby small electrical components are imbedded in epoxy casting resins by using acrylic molds.

The Colombo Extruder—Dipl.-Ing. S. Beyer

This article describes the development of twin-screw extruders. The development was necessary with the introduction of PVC suspension polymers, unplasticized PVC and high density polyethylenes.

High-Capacity Plant for the Impregnation of Paper with Synthetic Resin—W. Gutenberger

High-capacity plants for the production of synthetic resin impregnated laminates which provide more economical operation were required with the increased use of these laminates for technical and decorative purposes. The article describes such a plant utilizing thermosetting synthetic resins with absorbent papers with special emphasis on combining large drying capacity with space economy.

Steel-Supported Flexible PVC Extrusions and Their Use as Constructional Elements for Windows, Doors and Partitions—Dipl.-Ing. R. Frenz

Although plastics have proven themselves quite beneficial in interior decoration, they still require some sort of support. To this end structures are described utilizing a square steel support covered with an extruded sleeve of plasticized PVC. Included are examples of installations as elements for windows, doors and partitions as well as results of structural tests on the individual components.

The Installation of Plastics Pipelines—Ing. A. Minikus

Advantages and disadvantages of rigid PVC and high-pressure polyethylene are described when these materials are used in either pipe or pipe fittings. In particular, the thermal expansion must be considered when planning to use rigid PVC pipe. Proven methods of joining pipe are discussed.

Strength of Screw Joints in Plastics—Dr.-Ing. H. Peukert

Screw threads in plastics have not held up as well as desired because of the low shear strength of plastics materials used. A new type of joint, the Ensat joint, eliminates this difficulty—even with notch sensitive materials. The mechanical behavior was also studied with special reference to mechanical strength, behavior on bending and tensile strength.

May, 1958

Abstracter: Charles S. Imig

Cellular PVC by Gas Absorption at High Pressures—Herbert Lindemann

A new method for preparing PVC foams is described. Conventional methods utilize the decomposition of gas-releasing compounds which are added to the resin. This new method, which is claimed will overcome many difficulties, utilizes the absorption of gas at high pressures. Either powders or pastes may be used if suitably stabilized. Care must be taken to use gas mixtures which do not allow cell collapse so that dimensional stability may be maintained.

Factors Influencing Transparency of Glass Fiber Reinforced Polyesters—Civ.-Ing. L. Turunen and Civ.-Ing. B. Berndttsson

The influence of different catalyst systems, accelerators, temperature and setting time, post-curing, impregnation and addition of monomeric styrene, glass content and thickness of the sheet were studied for their effect on light transmission and light scattering.

Synthetic Resins for Glass Fiber Reinforced Plastics—Dr.-Ing. H. Sauer

The proper resin to use in glass fiber reinforced plastics depends on the properties of the resin, processing conditions, price and other factors. A number of possible resins are discussed in light of their properties and how they may be used most effectively to produce the most suitable end product.

Testing the Corrosive Influence of Plastics on Metals—Dipl.-Phys. E. P. Weissler

In telephone networks, plastics must not exert any corrosive influence on metals in damp atmospheres and under tropical climates. Test methods are described and possible causes of the corrosion discussed.

Use of Plastics Wrappings to Protect Pipelines Against Soil Corrosion—Dr. Richard Röhm

Results of five years underground exposure of PVC and polyethylene wrapped pipe are reported. In addition, the method used in wrapping the pipe and fittings is described.

Metallic Bonds—Part I: Conditions for Perfect Adhesive Bonds—Dr.-Ing. Heinz Peukert

The use of special purpose synthetic resin adhesives has made it possible to obtain permanent and highly effective bonds, although they have been used only in light construction work. The physical bases for this bond formation are described in addition to the conditions necessary for the formation of a perfect bond.

★

UNITED STATES

MATERIALS IN DESIGN ENGINEERING

June, 1958

Abstracter: Leonard Buchoff

Reinforced Plastics at 3,000 to 25,000°F—M. W. Riley

Materials for rocket components may be subjected to streams of combustion products at 5000 to 7000°F or ram air skin friction causing possibly 25,000°F. Certain reinforced plastics perform better than metals because of their higher heat capacity, ability to generate insulating gas blanket on heating and low thermal conductivity.

At the higher temperature (12,000 to 22,000°F) phenolics with organic reinforcements provide the best results. At 4000 to 5400°F phenolics reinforced with high silica glass fibers or asbestos show lowest erosion rates. A chart is given that summarizes results of other laminate systems.

Guide to Materials Standards and Specifications, Part 4—Plastics and Rubber—S. P. Kaidanovsky

Specifications of government and technical societies are described and listed. This article is a very valuable and handy reference for plastics and elastomers.

July, 1958

Abstracter: Leonard S. Buchoff

The New Polyethylenes—Part I—Malcolm W. Riley

Generally, an increase in the density of polyethylene provides greater rigidity and strength, high-

er temperature resistance, a harder glossier surface, higher resistance to creep and stress-rupture, lower permeability to fluids and gases, and decreased film coefficient of friction, but also a decrease in impact strength and flex life.

A decrease in melt index provides increased impact strength, greater resistance to environmental stress cracking, higher elongation, lower brittleness temperature, and improved creep and stress-rupture resistance. As melt index increases melt fluidity and "drawability" decrease, thus increasing process difficulties.

The article contains charts and tables which compare properties as functions of density and melt index.

★

ELECTRICAL MANUFACTURING

May, 1958

Abstracter: W. A. Kelley

Plastics and Ceramic Foams for Electronic Applications—William R. Cuming

The combination of light weight and unique dielectric properties has opened up a new field for plastics and ceramic foam materials in electronic equipment design. The plastics foams discussed include polyurethane, polystyrene, epoxies, silicone, phenolic and polyethylene. Various methods of application are discussed and property data are included for typical compounds. Selected case histories are illustrated.

June, 1958

Abstracter: W. A. Kelley

Conductive Adhesive for Electronic Applications—T. J. Kilduff and A. A. Benderly

In electronic equipment design it is often necessary to provide for both mechanical and electrical connection of various materials whose intrinsic properties prohibit conventional soldering. A silver-epoxy formulation described in this article is capable of complete cure at temperatures no higher than 100°C. When heated for one hour at this temperature it has a volume resistivity of approximately 0.5 ohm-cm and can produce bond strengths greater than 4000 psi. Applications include the preparation of surfaces of plastics and other non-conductors so they can be electroplated, and the repair of printed circuits in the vicinity of temperature-sensitive components.

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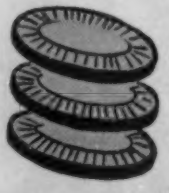

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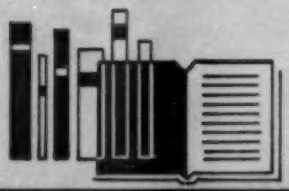

BOOK REVIEWS

Plastics in Building

E. F. Mactaggart and H. H. Chambers. Philosophical Library, Inc., New York, 1955. 181 pp., $12.00.

The first chapters deal with molecular structure, unsaturation, polymerization and chemistry of large molecules. Many excellent charts illustrate the essential points of the text.

The following chapters describe the manufacture of synthetic resins, their molding, extrusion and fabrication by other processes. Other chapters cover laminates, wood veneers, synthetic rubbers, fibers, textiles, silicones and recent developments in the use of plastics in building. The last pages contain a glossary and a list of trade names. The book is well illustrated with color plates, isotope charts and technical tables.

This is a good textbook on a very timely subject.

Dr. Louis C. Barail
Barail Associates

Ceramic Fabrication Processes

W. D. Kingery, Editor. The Technology Press of the Massachusetts Institute of Technology & John Wiley & Sons, Inc., New York, 1958. 235 pp., $9.50.

Glass, and some ceramics, are high polymers; further, they are usually fabricated while in the plastic state. The parallel between ceramic technology and plastics technology is so nearly complete that engineers in these fields should be able to benefit from each other's methods. Plastics engineers interested in plastisols would do well to read the chapters on Slip Casting and Plastic Forming; for understanding of polyethylene behavior, see the chapters on Ceramic Microstructures.

This book gathers together a well-rounded scientific presentation of the principles, theory and practice of ceramic fabrication. The accent on conceptual understanding of the processes is gratifying.

E. H. Merz
Monstanto Chemical Company

Industrial Chemicals, Second Edition

W. L. Faith, Donald B. Keyes and Ronald L. Clark. John Wiley & Sons, Inc., New York, 1957. 844 pp., $16.00.

This edition has been enlarged and shows many important changes. Following the progress and trends of modern industrial chemistry, it has added new chapters on newer chemicals and new data on previously treated subjects. A few natural products have also been added because new or expanded uses make them more valuable.

The reader will find here in detail the manufacturing or extracting processes of each chemical, its properties, grades, packaging and shipping regulations,

economic aspects, and a list of its manufacturers. The diagrams are exceptionally clear and the text is easy to read.

Plastics engineers will find in this book concisely written reminders of things they know well, and much more information on chemicals they may have to use which are not so familiar. In the first category, they will find the various plastics and plasticizers. In the second, an impressive list of solvents, dyes, additives, catalysts and other chemicals of high compounding and manufacturing value.

There is a company index and a subject index in which all uses of each chemical can be found.

This book is definitely a must for progressive plastics engineers.

Dr. Louis C. Barail
Barail Associates

Radioisotopes, A New Tool For Industry

Sidney Jefferson. Philosophical Library, Inc., New York, 1958. 110 pages, $4.75.

Sidney Jefferson, Leader of the Technological Irradiation Group, Isotope Division, at the British Atomic Energy Research Establishment at Harwell, has written a readable little book, suggesting areas of possible industrial applications of radioisotopes. The plastics engineer may find useful hints, particularly in the sections on thickness measurement, leakage detection, checking the thoroughness of mixing, and level and density measurement. No information is given on the accuracy that can be expected by these methods, or how they compare in cost or reliability with other methods now in use. The last portion of the book comprises four chapters on "Elementary Fundamentals of Radioactivity".

The treatment, which is non-mathematical, is lucid and can be read to good advantage even by those who have limited interest in the industrial applications. The book is well printed and replete with good photographs and diagrams. It would benefit in future editions by adequate bibliographical reference to the reader who would learn more, and by refernce to the commercial availability of suitable instruments for the reader who would put the author's hints into practice.

Charles H. Fuchsman
Ferro Chemical Corp.

American Institute of Physics Handbook

Edited by Dwight E. Gray, McGraw-Hill Book Co., New York, 1957. 1500 pp., $15.00.

This large size reference book puts at the reader's fingertips essential data in the various fields of physical science. It is divided into eight fundamental sections: mathematical aids to computation, mechanics, acoustics, heat, electricity and magnetism, optics, atomic and molecular physics, nuclear physics; the first section is mostly bibliography.

The book seems to cover every phase thoroughly. The amount of useful data is amazing, as is the high technical level. It has been well edited and attractively printed, and is enriched by hundreds of tables, charts, graphs, pictures and diagrams.

Prepared by more than ninety specialists under the sponsorship of the American Institute of Physics, the book is a must for all engineers and a very precious desk companion.

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